The New England Journal of Medicine

VOLUME 342 FEBRUARY 17, 2000 NUMBER 7

THE EFFECT OF WEIGHT LOSS IN OVERWEIGHT, LACTATING WOMEN ON THE GROWTH OF THEIR INFANTS

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ABSTRACT

Background The retention of weight gained during pregnancy may contribute to obesity. Lactation should promote weight loss, but weight loss is highly variable among lactating women. The risks associated with the restriction of energy intake during lactation have not been adequately evaluated. The purpose of this study was to determine whether weight loss by women during lactation affects the growth of their infants.

Methods We randomly assigned 40 breast-feeding women who were overweight (defined as a body-mass index [the weight in kilograms divided by the square of the height in meters] of 25 to 30) at 4 weeks post partum either to restrict their energy intake by 500 kcal per day and to exercise for 45 minutes per day for 4 days per week (the diet-and-exercise group) or to maintain their usual dietary intake and not exercise more than once per week for 10 weeks (the control group). We measured the weight and fat mass of the women and the weight and length of the infants before, during, and at the end of the study period.

Results The mean (±SD) energy intake decreased by 544±471 kcal per day in the diet-and-exercise group. As compared with the control group, the women in the diet-and-exercise group lost more weight (4.8±1.7 kg vs. 0.8±2.3 kg, $P<0.001$) and fat mass (4.0±2.0 kg vs. 0.3±1.8 kg, $P<0.001$). The gains in weight and length of the infants whose mothers were in the diet-and-exercise group (1925±500 g and 7.8±2.0 cm, respectively) were not significantly different from those of the infants whose mothers were in the control group (1861±576 g and 7.3±1.7 cm).

Conclusions Weight loss of approximately 0.5 kg per week between 4 and 14 weeks post partum in overweight women who are exclusively breast-feeding does not affect the growth of their infants. (N Engl J Med 2000;342:449-53.)

THE prevalence of overweight and obesity is increasing among women in the United States, with a recent report estimating that 51 percent of women have a body-mass index (the weight in kilograms divided by the square of the height in meters) of more than 25.[1] Retention of weight gained during pregnancy may contribute importantly to obesity. Theoretically, lactation promotes weight loss during the postpartum period, but in fact, weight loss during lactation is highly variable, and some women gain weight during lactation.[2]

In a report on nutrition during lactation, the Institute of Medicine stated that weight loss of up to 2 kg per month in overweight women appears to be safe and that weight loss of more than 2 kg per month is not advisable for women who are breast-feeding.[3] However, there have been no randomized trials supporting these statements. Therefore, we evaluated the effect of weight loss in overweight, lactating women on the growth of their infants.

METHODS

We conducted a randomized trial of a 10-week program that included restriction of energy intake and aerobic exercise designed to promote weight loss at a rate of 0.5 to 1.0 kg per week, beginning at the end of the 4th week post partum in women with a body-mass index of 25 to 30 at that time. Women who were healthy (defined as having no chronic illness), sedentary (defined as engaging in exercise no more than once per week during the previous three months), nonsmoking, and exclusively breast-feeding and who had given birth to full-term infants weighing at least 2500 g, had not delivered by cesarean section, and agreed to random assignment were recruited for the study. After base-line measurements were obtained, the women were randomly assigned (after stratification according to the sex of their infants, with the use of a random-number table[4]) to the diet-and-exercise group or to the control group. The women in the control group were instruct-

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ed not to restrict their energy intake and not to perform vigorous aerobic exercise more than once per week. All women were given a multivitamin supplement to be taken daily that contained at least 50 percent of the recommended dietary allowances for lactating women. The protocol was approved by the human-subjects committee of the institutional review board at the University of North Carolina at Greensboro, and all women gave written informed consent.

Anthropometric Measurements and Measurements of Body Composition

The women were weighed on a stationary-beam balance while wearing bathing suits at base line (4 weeks post partum), in the middle of the 10-week study period (9 weeks post partum), and at the end of the study period (14 weeks post partum). At the same times, the women's height without shoes was measured with the use of a stationary stadiometer; skin-fold thickness was measured with Harpenden calipers according to standardized methods by a single investigator at six body sites: triceps, midaxillary line, subscapular area, abdomen, suprailiac area, and thigh[5]; and body density was measured by underwater weighing. Before submersion in the tank, residual lung volume was measured with an oxygen-dilution technique.[6] Body density and the percentage of body fat were calculated with the use of the formulas of Brožek et al.[7] The weights of the women and infants and the lengths of the infants were also measured weekly in the home by a research assistant using a portable digital scale (Seca, Columbia, Md.) and a portable pediatric measuring board.

Dietary Intake

The women used portable digital scales (Ohaus, Florham Park, N.J.) to weigh all foods and beverages consumed for 3 consecutive days at base line, in the middle of the study period, and at the end of the 10-week study period. The Nutritionist IV software program (version 2.0, N^2 Computing, Salem, Oreg.) and food-composition tables were used to analyze the women's diets.[8]

Cardiovascular Fitness

A modified Balke protocol was used to estimate the level of cardiovascular fitness at base line and at the end of the study.[9] After a five-minute warm-up on a treadmill, the speed was increased to 5.4 to 5.9 km (3.4 to 3.7 mi) per hour and remained constant for the duration of the test. The women's heart rates and perceived levels of exertion were recorded every minute. Every two minutes the grade of the treadmill was increased by 2.5 percent. The test continued until the heart rate reached 85 percent of the predicted maximal heart-rate reserve: [(maximal heart rate − resting heart rate) × (0.85)] + resting heart rate. The predicted maximal heart rate was estimated as 220 − age in years.[9] The predicted oxygen consumption was calculated for each heart rate after every two minutes at each grade level with the following equation for walking: (3.5 ml of oxygen per kilogram per minute) + (speed in meters per minute × 0.1) + (grade × meters per minute × 1.8).[9] The predicted oxygen consumption at the maximal heart rate was calculated with a linear regression equation, with the heart rate as the independent variable and oxygen consumption as the dependent variable.

Weight-Loss Program

Energy requirements were estimated with the use of the Harris–Benedict equation, with an activity factor of 1.35 (defined as a moderate activity level).[10] An additional 630 kcal was added to compensate for lactation. This number was based on the estimation that the average energy content of breast milk is 70 kcal per 100 ml and the daily volume of milk is 750 ml with an 80 percent production efficiency.[11] The prescription for energy intake was determined by subtracting 500 kcal from the average of two values: the reported daily energy intake at base line and the estimated energy requirement. No woman was prescribed a diet of less than 1800 kcal per day. Each diet prescribed contained 25 percent of energy from fat, 20 percent from protein, and 55 percent from carbohydrates. Women in the diet-and-exercise group were given six commercial low-fat and low-calorie frozen dinners each week to assist with compliance.

The exercise program consisted of four 45-minute sessions each week at an intensity of 65 to 80 percent of the woman's maximal heart-rate reserve. The women wore heart-rate monitors (Polar, Port Washington, N.Y.) to confirm that they were exercising at the prescribed intensity. The duration of exercise, initially 15 minutes, was increased by at least 2 minutes every day until the women were exercising for 45 minutes at a level that was within their target heart-rate range, usually by the end of the fifth week of the study. The types of exercise included brisk walking, jogging, and aerobic dancing. A research assistant monitored the women's heart rate and compliance at each session.

Statistical Analysis

Data were analyzed with the use of SPSS-PC software (SPSS, Chicago).[12] The base-line characteristics of the two groups were compared with use of Student's t-test or the chi-square test. Changes over time and between groups were evaluated with repeated-measures analysis of variance. Differences between groups with respect to the growth of the infants were evaluated with analysis of covariance, with the differences between the end-point and base-line measurements of the weight and length of the infants as the outcome variables, and weight and length of the infants at the beginning of the study and their sex as the covariates. All P values are two-tailed.

RESULTS

A total of 48 women were enrolled in the study; 27 were randomly assigned to the diet-and-exercise group, and 21 to the control group. However, eight women (six in the diet-and-exercise group and two in the control group) did not complete the study; five returned to work full time and were not able to breast-feed their infants exclusively, two women withdrew because of personal problems, and mastitis developed in one woman, who discontinued breast-feeding as a result. There were no significant differences between the two groups in the base-line characteristics of the women (Table 1). The base-line characteristics of the eight women who discontinued the study were similar to those of the women who completed the study, except that the women who withdrew were significantly heavier before pregnancy ($P=0.005$) and at the beginning of the study ($P=0.05$), tended to have higher body-mass-index values ($P=0.07$) and heavier infants at birth ($P=0.06$), and had a lower level of cardiovascular fitness ($P=0.04$).

During the 10 weeks of the study, the women in the diet-and-exercise group lost between 1.7 and 8.3 kg (mean, 4.8), whereas the weights of the women in the control group varied from a gain of 4.6 kg to a loss of 4.6 kg (mean, a loss of 0.8 kg; $P<0.001$) (Table 2). Weight loss was predominantly due to a loss of fat mass. Changes from base line in all measurements of skin-fold thickness differed significantly between the groups ($P<0.01$). At the end of the study, 8 of the 21 women in the diet-and-exercise group (38 percent) had a body-mass index below 25, as compared with only 2 of the 19 women in the control group (11 percent). In addition, 10 of the

21 women in the diet-and-exercise group (48 percent) were within 1 kg of their prepregnancy weight, as compared with 4 of the 19 women in the control group (21 percent).

Two women in the diet-and-exercise group and three in the control group did not keep complete dietary records for all three measurement periods and were excluded from the dietary analysis. The women in the diet-and-exercise group decreased their energy intake more than the women in the control group did, but the difference was not statistically significant ($P=0.07$). All the women in the diet-and-exercise group but one were able to exercise four days a week. The exercise program improved cardiovascular fitness: the predicted maximal oxygen consumption increased by 13 percent in the diet-and-exercise group, as compared with 2 percent in the control group ($P=0.009$). According to the categories of fitness of the American College of Sports Medicine, the fitness level of the women in the diet-and-exercise group increased from "average" to "excellent," whereas the women in the control group remained in the level of "average."[13]

There were no significant differences between the groups in the infants' gain in weight or length (Table 3). The mean difference between groups in the infants' change in weight from base line was 64 g (95 percent confidence interval, −280 to 409). Because five women in the control group lost more than 3 kg (range, 3.2 to 4.6) and three women in the diet-and-exercise group lost less than 3 kg (range, 1.7 to 2.9), the data were reanalyzed according to a different grouping: the 23 women who lost 3 kg or more (mean [±SD] loss, 4.9±1.5) and the 17 women who gained weight or lost less than 3 kg (mean loss, 0.2±1.8). The infants' mean gains in weight and length were similar to those observed with the initial groupings, and there were no significant differences between the groups.

TABLE 1. BASE-LINE CHARACTERISTICS OF THE STUDY SUBJECTS.*

CHARACTERISTIC	DIET-AND-EXERCISE GROUP (N=21)	CONTROL GROUP (N=19)
Age (yr)	31±4	33±4
Race (no.)		
White	17	16
Black	4	3
Parity (no.)		
1	8	2
≥2	13	17
Height (cm)	165.5±5.8	165.6±5.0
Weight (kg)	75.9±9.3	76.8±7.8
Body-mass index†	27.6±2.4	28.0±2.1
Prepregnancy weight (kg)	68.9±8.3	71.8±10.0
Weight gain during pregnancy (kg)	15.3±3.6	15.9±5.2
Maximal oxygen consumption (ml/kg/min)	35.1±3.5	35.2±5.4
Weight of infant (kg)		
Birth	3.69±0.53	3.65±0.38
4 wk	4.80±0.72	4.46±0.42
Sex of infant (no.)		
Female	9	9
Male	12	10

*Plus–minus values are means ±SD.

†The body-mass index is the weight in kilograms divided by the square of the height in meters.

DISCUSSION

This study demonstrates that moderate weight loss of approximately 0.5 kg per week in overweight, lactating women does not affect the growth of their infants in terms of weight and length. In the diet-and-exercise group, the average weight gain among male infants was 28.1 g per day, and among female infants it was 26.7 g per day, values similar to those among the infants in the control group, as well as those reported by other researchers. In the study by Nelson et al., among 203 male infants and 216 female infants studied between 7 and 16 weeks of age, the average gains were 25.4 g per day and 22.6 g per day, respectively.[14] Similarly, average gains of 27.7 g per day among 109 male infants and 23.6 g per day among 117 female infants from one to four months of age were reported in an evaluation by the World Health Organization of the growth of infants who were exclusively breast-fed.[15]

Our results are similar to those reported by Dusdieker et al., who restricted the energy intake of 33 lactating women by approximately 500 kcal per day for 10 weeks, beginning at 4 weeks post partum.[16] They reported that an average weight loss of 4.8 kg did not reduce the volume of milk or the content of fat or protein. The 22 infants for whom complete data were available gained an average of 21 g per day. However, there was no control group, and 33 percent of the women discontinued the study. The women who withdrew had significantly lower base-line energy intake and tended to have lower measurements of skin-fold thickness and milk volume at base line than the 22 women who completed the study.

In a study of 14 women, one week of energy restriction did not affect the production of milk.[17] However, during the week after the diet, the volume of milk decreased in women who consumed less than 1500 kcal per day. In another study, McCrory et al. found that an energy deficit of 35 percent in 44 women, achieved by dieting alone or by dieting with exercise for 11 days, had no significant effect on the weight gain of their infants or on the volume or composition of their milk.[18] However, the short duration of these studies limits the conclusions that can be drawn about energy restriction during lactation.

The women who lost weight in the diet-and-exercise group in our study did lose fat-free mass, but the difference between the groups in the loss of fat-

TABLE 2. BODY COMPOSITION, ENERGY INTAKE, AND LEVEL OF CARDIOVASCULAR FITNESS.*

VARIABLE	BASE LINE (4 WK POST PARTUM)	MIDPOINT OF STUDY (9 WK POST PARTUM)	END OF STUDY (14 WK POST PARTUM)	CHANGE FROM BASE LINE†
	mean ±SD			
Weight (kg)				
Diet-and-exercise group	75.9±9.4	73.2±9.1	71.0±8.8	−4.8±1.7‡
Control group	76.8±7.8	76.6±8.2	76.0±8.8	−0.8±2.3
Body-mass index§				
Diet-and-exercise group	27.6±2.4	26.7±2.4	25.9±2.3	−1.8±0.6‡
Control group	28.0±2.1	27.9±2.2	27.5±2.5	−0.3±0.9
Body fat (% of body weight)				
Diet-and-exercise group	33.8±3.3	32.0±3.0	30.4±2.9	−3.3±1.8‡
Control group	33.2±4.0	33.4±4.7	33.0±4.3	−0.2±1.8
Fat mass (kg)				
Diet-and-exercise group	25.8±5.1	22.6±6.8	21.8±4.2	−4.0±2.0‡
Control group	25.6±4.9	25.8±5.6	25.3±5.5	−0.3±1.8
Fat-free mass (kg)				
Diet-and-exercise group	50.1±5.2	50.6±5.8	49.3±5.3	−0.8±1.1
Control group	51.2±4.7	50.8±5.2	50.6±5.0	−0.6±1.6
Skin-fold thickness (mm)				
Triceps				
Diet-and-exercise group	24.7±5.0	24.7±4.7	23.3±4.3	−1.3±3.1‡
Control group	25.0±4.2	26.9±3.8	27.2±4.7	2.1±3.1
Subscapular area				
Diet-and-exercise group	24.3±6.3	21.3±6.4	19.4±6.7	−4.9±3.6‡
Control group	23.7±6.9	25.3±6.9	25.1±9.5	2.5±6.5
Midaxillary line				
Diet-and-exercise group	16.2±3.6	14.6±4.1	14.1±4.6	−2.1±3.4‡
Control group	15.3±4.8	16.6±4.7	16.2±4.8	0.8±2.1
Abdomen				
Diet-and-exercise group	31.1±5.9	27.6±5.7	25.9±6.2	−5.2±4.1‡
Control group	28.6±6.0	30.2±5.5	29.8±6.9	1.7±5.2
Suprailiac area				
Diet-and-exercise group	19.8±5.3	18.0±5.5	15.7±5.0	−4.1±2.8‡
Control group	18.7±6.2	19.1±4.8	18.6±5.9	−0.1±3.0
Thigh				
Diet-and-exercise group	48.7±11.3	44.9±10.1	38.9±10.8	−9.9±6.3‡
Control group	49.3±9.7	47.2±11.1	46.0±10.6	−3.3±5.3
Energy intake				
Kilocalories per day				
Diet-and-exercise group	2213±574	1736±408	1669±293	−544±471
Control group	2378±436	2230±577	2142±540	−236±508
Kilocalories per kilogram per day				
Diet-and-exercise group	29.5±8.1	23.9±5.3	22.8±4.8	−5.7±6.1
Control group	31.0±5.8	29.1±7.8	28.3±7.8	−2.7±6.9
Maximal oxygen consumption (ml/kg/min)				
Diet-and-exercise group	35.1±3.5	—	39.7±5.4	4.5±4.9‡
Control group	35.2±5.4	—	35.8±6.6	0.6±3.8

*Values are for 21 women in the diet-and-exercise group and 19 women in the control group for all variables except energy intake, for which 19 and 16 women, respectively, are included.

†Values for change were calculated by subtracting the base-line measurement from the end measurement for each subject and then averaging the results for each group.

‡$P<0.01$ for the interaction of time with group.

§The body-mass index is the weight in kilograms divided by the square of the height in meters.

free mass was not significant. In the 11-day study by McCrory et al., the weight lost in the dieting-only group consisted of 67 percent fat and 33 percent fat-free mass, whereas the weight lost in the group that dieted and exercised consisted only of fat.[18] Although the women in our study were dieting and exercising aerobically, they did not exercise as much or as often as the women in the diet-and-exercise group in that study (83 minutes per day), and we began the intervention earlier (4 weeks post partum vs. 12 weeks post partum). The loss of fat-free mass in the women in our study may reflect changes in body composition that occur during the early postpartum period (i.e., loss of body water). Lactating women lose sig-

TABLE 3. GAINS IN WEIGHT AND LENGTH AMONG THE WOMEN'S INFANTS DURING THE 10-WEEK STUDY PERIOD.*

VARIABLE	DIET-AND-EXERCISE GROUP (N=21)	CONTROL GROUP (N=19)
	mean ±SD	
Gain in weight (g)		
All infants	1925±500	1861±576
Female infants	1869±483	1667±486
Male infants	1968±530	2036±618
Gain in length (cm)		
All infants	7.8±2.0	7.3±1.7
Female infants	7.7±1.1	6.8±1.5
Male infants	7.9±2.7	7.8±1.8

*There were no significant differences between the groups.

nificantly more potassium and water than nonlactating women between two weeks and three months post partum, indicating a greater loss of fat-free mass among lactating women than among nonlactating women; however, between three and six months post partum, loss of fat is greater among lactating women than among nonlactating women.[2]

Loss of fat occurred at all skin-fold sites in the women in the diet-and-exercise group, whereas measurements of skin-fold thickness at the triceps, subscapular area, and midaxillary line increased in the women in the control group. The results of skin-fold measurements at the triceps in other studies of women who were not dieting or exercising during lactation were similar to those in the women in our control group.[2]

Our results indicate that overweight women may lose moderate amounts of weight safely during lactation, but the results might be different for women with body-mass-index values of less than 25. The women in this study had adequate energy reserves; their average percentage of body fat was 33.8 percent. There is also the potential for bias in this study, because the women who left the study were heavier before pregnancy and at the beginning of the study and had a lower level of cardiovascular fitness than the women who completed the study.

In conclusion, a program of moderate exercise and energy restriction was successful in inducing weight loss in overweight, lactating mothers without harming the growth of their infants in the early postpartum period. Our results therefore support the recommendation by the Institute of Medicine that if a lactating woman is overweight, weight loss of up to 2 kg per month is unlikely to affect milk production adversely.[3]

Supported by grants from the National Institutes of Health (HD 34222) and the North Carolina Agricultural Research Service.

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