The Journal of Maternal-Fetal Medicine 7:89–94 (1998)

Interpregnancy Weight Retention Patterning in Women Who Breastfed

MaryFran Sowers, PhD,* Daowen Zhang, MS, and Carol A. Janney, MS

Department of Epidemiology, School of Public Health, University of Michigan, Ann Arbor, Michigan

Abstract This study compares weight change in lactating women with an 18-month interpregnancy interval with woman who also breastfed but did not have an immediate subsequent pregnancy. Cases were women who breastfed an index infant for 6 months and subsequently became pregnant within 18 months (cases = 25), and the controls also breastfed an index infant for 6 months but had no ensuing pregnancy (controls = 20) within 18 months. The pattern of postpartum weight retention following the initial pregnancy was not statistically different in cases compared to the controls. However, following their ensuing subsequent pregnancy, cases were 1.3 kg heavier than their average weight after their baseline pregnancy ($P = 0.02$). The best predictor of this greater weight was their weight change during the interpregnancy interval ($P = 0.03$). Total weight gain during the gestational period of the subsequent pregnancy was not associated with the greater weight following the subsequent pregnancy. Likewise, estimates of the amount of energy as calories or physical activity levels were not significant predictors of this greater weight following the subsequent pregnancy. These findings suggest that monitoring of postpartum weight, even in breastfeeding women, is essential. These findings indicate that breastfeeding women begin the next postpartum interval weighing more than the amount observed in the initial postpartum period. *J. Matern.–Fetal Med. 7:89–94, 1998.* © 1998 Wiley-Liss, Inc.

Key Words: weight retention pattern; lactation; pregnancy; obesity; postpartum weight

INTRODUCTION

The contribution of interpregnancy interval length on postpartum weight retention is largely unknown. Even more specifically, it is not known whether breastfeeding women with a relatively short interpregnancy interval have a different weight retention pattern than other breastfeeding women who did not have the shorter interpregnancy interval.

Although the interpregnancy interval has been examined for its contribution to risk of preterm labor [1], low birthweight [2–5], or other poor outcomes of the newborn [6,7], interpregnancy interval rarely has been considered for its impact on maternal status, including an association with postpartum weight retention pattern. In one of the few examples where maternal status was considered, Greene et al. [8] reported that weight gain in the first pregnancy was related to weight change between pregnancies among women, but the weight pattern during interpregnancy interval was not measured and the interpregnancy interval was quite wide, up to 6 years. Furthermore, breastfeeding characterization, which might affect the interpregnancy weight pattern, was identified only by whether women left the hospital breastfeeding or not.

The role of the interpregnancy interval upon weight retention is uncertain for women who breastfed. This is hardly surprising given inconsistent information about the role of lactation in postpartum weight retention in general. Some studies of lactation and weight retention reported a greater likelihood of weight loss with longer duration of lactation [9–11,14,15], with a diminution in the rate of loss as the postpartum period became more protracted. Other studies reported no difference between lactation practices and postpartum weight loss [12–15], or found that women who formula-fed rather than breastfed their infants had greater weight loss in the postpartum period [16–19]. In a longitudinal study, we demonstrated that women who breastfed their infants retained less weight over time compared to women who bottle fed their infants [21]. Thus interpretation of information about the interpregnancy

Contract grant number: R01 AR41310.

*Correspondence to: MaryFran Sowers, University of Michigan, Department of Epidemiology, Rm. 3073 SPH I, 109 S. Observatory, Ann Arbor, MI 48109-2029. E-mail address: mfsowers@umich.edu

Received 22 October 1997; revised 22 October 1997; accepted 23 October 1997

weight characteristics must be done while simultaneously considering the potential impact of type of infant feeding.

We hypothesized that breastfeeding women who experience a relatively brief interpregnancy interval are more likely to retain weight during that interpregnancy interval than other women who also breastfed but delay a subsequent conception for at least 24 months. We also hypothesized that postparturition weight after a subsequent pregnancy would be greater than the postparturition weight after an initial pregnancy if women had not returned to their baseline weight.

METHODS AND MATERIALS

Parent Population

Data for the 25 cases and 20 controls used in this substudy are from a parent population comprised of 115 women, aged 20–40 years and 0–1 parity. The women for the parent study were recruited for a study of bone mass and lactation in their third trimester of pregnancy from birthing education classes and obstetric practices located in the Ann Arbor, Michigan, area [21]. Women were eligible for the parent study if they intended to bottlefeed or breastfeed for at least 6 months. Women were not enrolled if they had any of the following: a history of endocrine, renal, liver, or chronic respiratory illness; complications of pregnancy including hypertension or gestational diabetes; complications at delivery including premature delivery (≤35 weeks); a hospitalization that exceeded 2 days; delivery of an infant small for gestational age (≤2,500 g); or twins. The characteristics of this parent population are shown in Table 1.

TABLE 1. Personal Characteristics of the 115 Postpartum Women of the Parent Population

Characteristic	Mean (sd)	Range
Age (yr)	29.3 (4.3)	20, 40
Height (cm)	164.1 (5.6)	152, 178
Weight prior to pregnancy (kg)	59.7 (9.7)	43, 93
Weight gained (kg)		
first trimester	3.1 (2.9)	−4.5, 11
second trimester	6.4 (3.0)	−6.8, 13.5
third trimester	6.5 (2.9)	1.4, 18.3
total	16.2 (5.3)	1.4, 35.9
Weight gain during second pregnancy (kg)	15.9 (4.2)	11, 25
Infants birth weight (kg)	3.5 (0.5)	2.4, 4.7
Body mass index prior to pregnancy (kg/m^2)	22.2 (3.4)	16.9, 33.8
	n	percentage
Parity: none	61	53%
one	54	47%

Substudy Cases and Controls

Enrollees in the parent study were evaluated in a longitudinal study design that included six measurements in the postpartum period at 0.5, 2, 4, 6, 12, and 18 months. The 25 women who subsequently became pregnant at any time during the 18-month follow-up period did not continue with the scheduled measurement intervals of the parent study. Instead, all these women were measured for the final time within 14 days of their subsequent delivery. These 25 breastfeeding women with a subsequent pregnancy were defined as "cases" in this substudy.

The 20 "controls" also breastfed but did not conceive during the 18 month follow-up period. These controls were frequency-matched with cases for timing of their measurements; 12 controls for this substudy were recalled for an additional measurement to correspond with the final measurement of those women who had become pregnant again. Thus if a case was identified as having conceived again at 15 months following the birth of her reference child, she did not participate in the 18-month measurement, but would have been measured within 0.5 months of the subsequent delivery (or at 22 months following the birth of her reference child). To match a case, a "control" would have completed the regular program of measurements at 0.5, 2, 4, 6, 12, and 18 months, but also would have been recalled for an additional measurement at 24 months following the birth of her reference child. One case and one control reported using contraception.

Measures

Weight (in kilograms) was measured with a calibrated scale at each interview. Weight prior to baseline pregnancy was self-reported. There were two weight change variables used in the analysis. "Postpartum weight retention," one of the outcome variables, was calculated by subtracting weight prior to the pregnancy of the reference infant from weight at each evaluation point during the postpartum period. The other outcome variable was "across pregnancy weight difference," which is the difference between the weight of the cases 2 weeks after the birth of the reference infant and 2 weeks following the birth of the subsequent infant. Information about the baseline percent body fat were derived from measurement of body composition by dual x-ray densitometry within 14 days of the delivery of the reference child. Midarm muscle and fat area were computed from midarm circumferences and triceps skinfold according to the formulas of Gray et al. [22].

Participants were interviewed at each visit for information about infant feeding practices, menstruation status, diet, and physical activity. Women were described as fully breastfeeding if they nourished their infant in a manner so that no more than 1/3 of calories were provided from formula, juice, or alternative milk sources. Nutrient intake was assessed using the validated food frequency instrument to characterize usual food intake in 6-month time periods [23]. Physical activity was quantified using a modification of the Stanford Five-City instrument. The instrument charac-

TABLE 2. Proportions of Cases and Controls Who Are Breastfeeding at Six Time Intervals Following Birth of Referent Child

Month after parturition	Breastfeeding		Partial breastfeeding		Bottlefeeding	
	Cases	Controls	Case	Controls	Case	Controls
0.5	25/25 (100%)	20/20 (100%)	0/25 (0%)	0/20 (0%)	0/25 (0%)	0/20 (0%)
2	23/25 (92%)	17/20 (85%)	2/25 (8%)	2/20 (10%)	0/25 (0%)	1/20 (5%)
4	20/25 (80%)	17/25 (85%)	0/25 (0%)	0/20 (0%)	5/25 (20%)	3/20 (15%)
6	20/25 (80%)	17/20 (85%)	0/25 (0%)	0/20 (0%)	5/25 (20%)	3/20 (15%)
12	1/24 (4%)	1/20 (5%)	4/24 (16%)	6/20 (30%)	19/24 (80%)	13/20 (65%)
18[a]	0/9 (0%)	0/19 (0%)	0/9 (0%)	2/19 (11%)	9/9 (100%)	17/19 (89%)

[a]Sample size decreased due to subsequent pregnancy.

TABLE 3. Selected Characteristics of Cases and Controls Around Time of Reference Pregnancy

Variables	Cases X ± SD	Controls X ± SD	*P* value
Number	25	20	
Age	29.4 ± 3.6	30.4 ± 3.6	0.38
Weight and body composition measures			
Weight gain during reference pregnancy	16.8 ± 2.5	15.9 ± 4.1	0.92
Baseline postparturition weight	65.5 ± 11.1	63.9 ± 8.2	0.77
Baseline Quetelet index (kg/m^2)	24.6 ± 4.1	24.0 ± 3.1	0.79
Baseline midarm muscle area (cm^2)	42.4 ± 10.0	43.1 ± 9.2	0.61
Baseline midarm fat area (cm^2)	3.4 ± 1.6	2.75 ± 1.3	0.18
Baseline percent body fat	28.6 ± 4.4	26.9 ± 4.8	0.18
Percent with previous child	27%	40%	0.03
Time to menses return (months)	7.4 ± 5.1	7.7 ± 6.2	0.76
Time from baseline to subsequent pregnancy (months)	15.4 ± 5.3	—	

terizes the METs per week of moderate, hard, and very hard activity with one MET (metabolic equivalent time) being defined as the amount of energy consumed per minute of sitting at rest [24].

Women were categorized at each evaluation according to whether menstruation had returned since parturition (0 = menstruation had not returned, 1 = menstruation returned). Menstruation was defined as two consecutive bleeding episodes lasting more than a single day and occurring within a 45-day period of time. One-time covariates assessed at the birth of the referenced infant were education ($0 \leq 16$ yr, $1 > 16$ yr), parity (0, 1), type of delivery (0 = vaginal, 1 = cesarean), season of delivery (winter, spring, summer with fall as the referent season), marital status (0 = married, 1 = other), age in years, and smoking prior to or during pregnancy (0 = no, 1 = yes).

Both the parent study and this substudy were approved by the Institutional Review Board at the University of Michigan.

Statistical Analyses

To assess the comparability of the controls with the cases, characteristics such as weight and bone density as well as lifestyle practices were compared using Fisher's exact tests for categorical variables and t-tests for continuous variables. In addition, paired t-tests were used to assess the change in weight between the baseline postparturition measure and the subsequent postpartum measure among the cases. Simple linear regression analysis was used to describe any factors that might explain the weight changes between the beginning of the initial or baseline postpartum period and subsequent postpartum measure including energy intake, energy expenditure, and weight gain during the subsequent gestational period.

The comparison of weight retention patterns for the cases and the controls was evaluated by longitudinal analysis using a nonparametric mixed model that does not assume a specific functional form for the weight retention curves. Random intercept and random slope, plus measurement error, were used to model the correlation and the variability in the repeated measurements (see Appendix).

RESULTS

Table 2 describes the proportion of cases and controls who were fully breastfeeding, partially breastfeeding, or bottlefeeding at each measurement time point for cases and controls following the birth of the reference infant. There was no statistically detectable differences between cases and controls as to their lactation practice ($P > 0.7$) with both

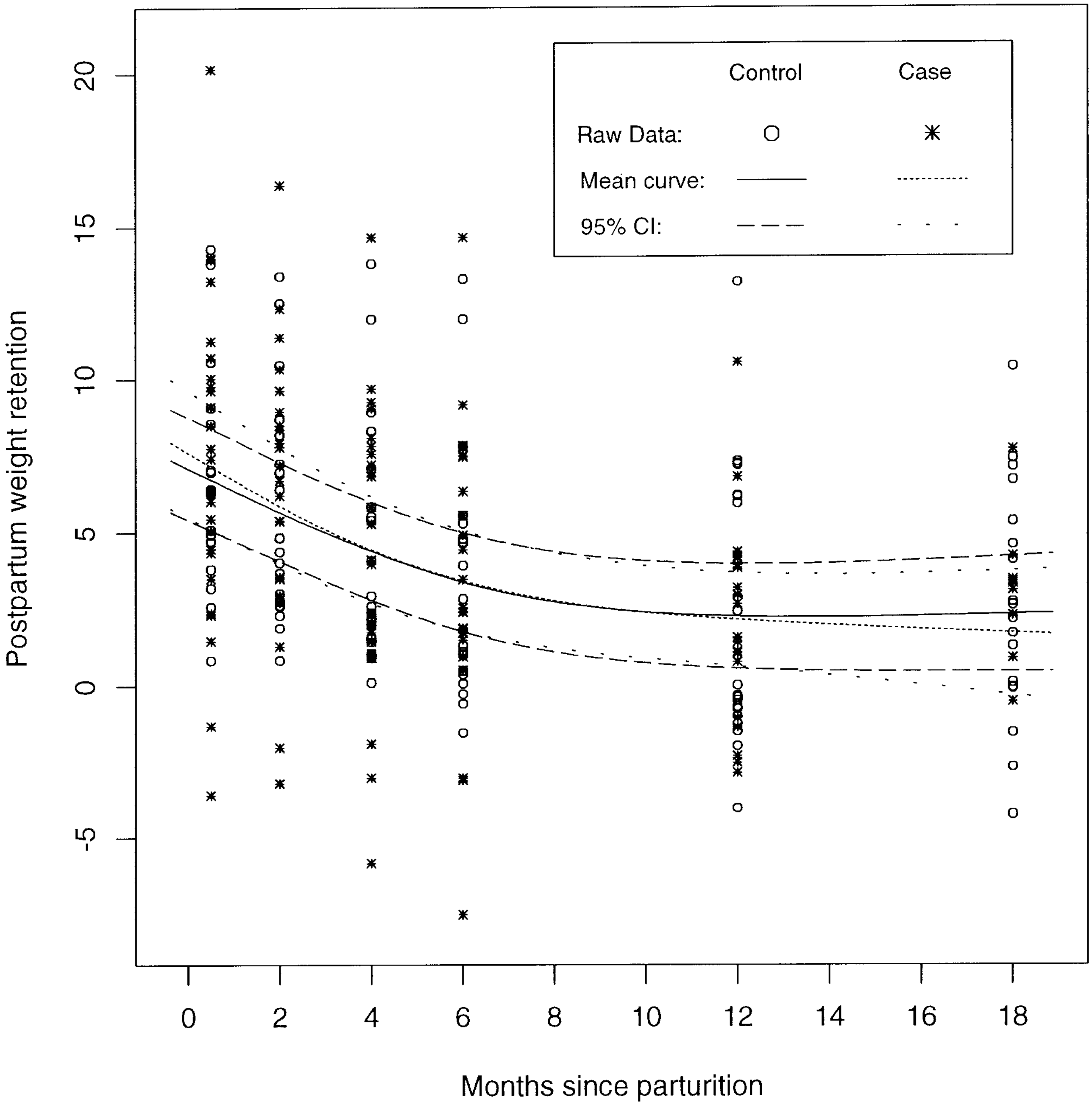

Fig. 1. Actual retained weights, average weight retention curves with 95% confidence intervals (CIs) for cases (lactating women with a subsequent pregnancy within 18 months of baseline parturition) and for controls (lactating women with *no* subsequent pregnancy within 18 months of a baseline parturition).

groups having progressed from intense breast feeding to limited breast feeding after the 6-month examination.

Table 3 contrasts selected characteristics of the cases and controls. There were no significant differences between the two groups for age or any measure of body composition following the reference pregnancy. The primary difference between the two groups was that women who were cases were more likely to have been nulliparous at the time of the reference birth, whereas controls were more likely to have had a single previous pregnancy.

The average weight loss in the postpartum period was 4.7 ($\pm$4.3) kg for cases and 4.4 ($\pm$3.0) kg for controls, which are not significantly different. Figure 1 presents a plot of each women's retained weight (kg) by months since parturition as well as the average weight retention curves with 95% confidence intervals for the cases and controls. There was

TABLE 4. Physical Activity and Caloric Intake Characteristics of Cases and Controls in Interval Between Baseline and Subsequent Pregnancy

	Cases	Controls	*P* value
Physical activity index (METS)			
0.5 month	201.2 ± 45.2	205.7 ± 42.9	0.74
2 months	290.6 ± 24.1	301.9 ± 21.1	0.10
4 months	292.4 ± 18.4	300.9 ± 18.6	0.13
6 months	293.1 ± 18.0	304.4 ± 20.8	0.06
12 months	299.1 ± 19.0	302.7 ± 14.6	0.50
18 months	297.9 ± 19.4	304.8 ± 30.1	0.47
Total calories			
0.5–6 months	2,072 ± 533	1,990 ± 449	0.58
6–12 month	1,970 ± 782	1,798 ± 559	0.40
12–18 months	1,991 ± 922	2,184 ± 679	0.59

no statistically significant difference between their weight retention patterns, because each confidence band includes the average weight retention curve for the other group. The average weight retention curve for the cases and controls have similar shapes; initially they decline and then begin to plateau at ~8–10 months postpartum. In estimating the curve for the cases, the retained weights were treated as missing for the women with subsequent pregnancy at the 12–month or 18–month time points. These missing data had no systematic pattern, therefore did not bias the estimated curve.

Table 4 depicts the measures of physical activity index and total energy intake (as calories) at each time point for the cases and controls. There were no significant differences between the two groups.

Among cases, we compared the postpregnancy weight measured at 0.5 months following the baseline pregnancy with the postpregnancy weight measured at 0.5 months following the subsequent pregnancy and found the difference was statistically significant. On average, cases weighed 1.3 kg ($P = 0.02$) more after the subsequent pregnancy than they had weighed following the baseline pregnancy. At their final measurement, controls weighed 4.59 kg (SD = 2.94) less than their postpregnancy baseline, but had no intervening pregnancy. The best predictor of this weight difference was amount of weight change over the interpregnancy interval for the cases (beta = 0.27 ± 0.12, $P = 0.036$). Weight gain during the subsequent gestational period (an average of 15.9 kg), age, calorie intake, or energy expenditure per se did not account for the weight difference between the first postparturition weight and the second postparturition weight.

DISCUSSION

Previously, we reported that the pattern of postpartum weight retention differed among lactating and nonlactating women; furthermore, the degree of weight retention was influenced by weight gain during pregnancy, age, and marital status [20]. Lactating women exhibited greater rates of weight loss than bottlefeeding women. Furthermore, they were more likely to return to their prepregnancy weight at an earlier date. Thus we chose to limit this report only to those women (both cases and controls) who had engaged in relatively long-term lactation. The effect is to remove the role of lactation per se in predicting the weight retention pattern of women who conceived within 18 months as opposed to not conceiving within 18 months.

We speculated that there was no difference in weight retention pattern between cases and controls because the subsequent pregnancy usually occurred more than 8 months following parturition. As shown in Figure 1, the major weight loss period occurred during the first 8–10 months following parturition. In this study, the women averaged 15.4 months between the delivery of the reference child and conception of the subsequent child. By 15 months postpartum, the rate of weight loss had, on average, plateaued.

Although the cases with a brief interpregnancy interval lost weight in the first 8–10 months of the postpartum period, they nonetheless weighed, on average, 1.3 kg more after the subsequent pregnancy as compared to the reference pregnancy. Our previous study [20], as well as others [12,13,16,25–28], found weight gain during pregnancy to be positively associated with postpartum weight retention. We found that the amount of weight change over the interpregnancy interval, not the weight gain during the subsequent pregnancy, predicted this weight difference. In this study, estimates of energy intake or physical activity were not important factors to explain the weight differential between the baseline postpartum weight and the subsequent postpartum weight.

Since subsequent pregnancy is a natural part of the reproductive cycle for women of childbearing age, these women may provide insight into the role of reproduction on the development of obesity while controlling for the effect of breastfeeding. If women have not achieved their prepregnancy weight prior to the subsequent pregnancy, women may increase their likelihood of continued weight accumulation.

There are limitations to these data that must be considered. Subtle differences in weight retention patterns between cases and controls might be difficult to observe because of the sample size; however, the use of longitudinal data analysis techniques should optimize the identification of important patterns. With samples the size of those in this study, we have the power to detect moderate to large differences by not small differences of less than one-four standard deviation. Measurement of diet and physical activity are notoriously difficult to assess, and measurement error may account for the lack of statistical significance in associating these variables with weight retention patterns. Our study participants were white nonsmokers with higher educational levels who might have a different interpregnancy interval experience than a more diverse population. Nevertheless, this study is the first longitudinally to analyze the impact of a brief interpregnancy interval on weight retention.

In summary, these data suggest that there is no evidence that women with an interpregnancy interval <18 months have a different weight retention pattern than other women who delay a subsequent conception >24 months. Further, there was a greater subsequent postpartum weight after the ensuing subsequent pregnancy that was associated with amount of weight loss in the interpregnancy interval. This higher weight, then, would represent a higher threshold level from which future weight patterns in subsequent pregnancies would develop.

APPENDIX

The following nonparametric mixed models were used to model the weight retention patterns for cases and controls:

$$Y_{ij} = f(t_{ij}) + Z_{ij}b_i + e_{ij}$$

where Y_{ij} is the retained weight for subject i at time t_{ij}, f(t) is a smooth function with continuous second derivatives. $Z_{ij} = (1, t_{ij})'$, b_i is a bivariate normal variable representing random intercept and slope, e_{ij} is the measurement error independent of b_i. The curve f(t) is estimated via maximizing the following penalized log-likelihood (26)

$$l_p(f,\theta;Y) = \sum_{i=1}^{m} l_i(f,\theta;Y_i) - \frac{\lambda}{2}\int_{T_1}^{T_2} (f''(t))^2 dt,$$

where $l_i(f,\theta;Y_i)$ is the log-likelihood contributed by $Y_i = (Y_{il}, \ldots, Y_{in_i})'$, data from subject i, $\lambda > 0$ is the smoothing parameter, (T_1, T_2) is an interval covering time t_{ij}, and θ is the parameter vector in the variance components b_i and e_{ij}. The smoothing parameter λ and the parameter vector θ are estimated via maximizing the REML log-likelihood function (27) treating f(t) as a random effect. The estimator $\hat{t}(t)$ is a natural cubic spline in (T_1, T_2) with knots t_{ij}.

REFERENCES

1. Lang JM, Lieberman E, Ryan KJ, Monson RR: Interpregnancy interval and risk of preterm labor. Am J Epidemiol 132:304–309, 1990.
2. Ferraz EM, Gray RH, Fleming PL, Maia TM: Interpregnancy interval and low birth weight: findings from a case-control study. Am J Epidemiol 128:1111–1116, 1988.
3. Brody DJ, Bracken MB: Short interpregnancy interval: A risk factor for low birthweight. Am J Perinatol 4:50–54, 1987.
4. Klebanoff MA: Short interpregnancy interval and the risk of low birthweight. Am J Public Health 78:667–670, 1988.
5. Adams MM, Delaney KM, Stupp PW, McCarthy BJ, Rawlings JS: The relationship of interpregnancy interval to infant birthweight and length of gestation among low-risk women, Georgia. Paediatr Perinat Epidemiol 11:48–62, 1997.
6. Spiers PS, Onstad L, Guntheroth WG: Negative effect of a short interpregnancy interval on birth weight following loss of an infant to sudden infant death syndrome. Am J Epidemiol 143:1137–1141, 1996.
7. Kallan JE: Effects of interpregnancy intervals on preterm birth, intrauterine growth retardation, and fetal loss. Soc Biol 39:231–245, 1992.
8. Greene GW, Smicklas-Wright H, Scholl TO, et al.: Postpartum weight change: How much of the weight gained in pregnancy will be lost after delivery? Obstet Gynecol 71:701–707, 1988.
9. Öhlin A, Rössner S: Maternal body weight development after pregnancy. Int J Obes 14:159–173, 1990.
10. Dewey KG, Heinig MJ, Nommsen LA: Maternal weight-loss patterns during prolonged lactation. Am J Clin Nutr 58:162–166, 1993.
11. Kramer FM, Stunkard AJ, Marshall KA, et al.: Breast-feeding reduces maternal lower-body fat. J Am Diet Assoc 93:429–433, 1993.
12. Schauberger CW, Rooney BL, Brimer LM: Factors that influence weight loss in the puerperium. Obstet Gynecol 79:424–429, 1992.
13. Brewer MM, Bates MR, Vannoy LP: Postpartum changes in maternal weight and body fat depots in lactating vs. nonlactating women. Am J Clin Nutr 49:259–265, 1989.
14. Dugdale AE, Eaton-Evans J: The effect of lactation and other factors on post-partum changes in body weight and triceps skinfold thickness. Br J Nutr 61:149–153, 1989.
15. van Raaij JMA, Schonk CM, Vermaat-Miedema et al.: Body fat mass and basal metabolic rate in Dutch women before, during, and after pregnancy: A reappraisal of energy cost of pregnancy. Am J Clin Nutr 49:765–772, 1989.
16. Olsen LC, Mundt MH. Postpartum weight loss in a nurse-midwifery practice. J Nurse Midwifery 31:177–181, 1986.
17. Potter S, Hannum S, McFarlin B, et al.: Does infant feeding method influence maternal postpartum weight loss? J Am Diet Assoc 91:441–446, 1991.
18. Rookus MA, Rokebrand P, Burema J, et al.: The effect of pregnancy on the body mass index 9 months postpartum in 49 women. Int J Obes 11:609–618, 1987.
19. Newcombe RG: Development of obesity in parous women. J Epidemiol Community Health 36:306–309, 1982.
20. Janney C, Zhang D, Sowers MF: Lactation and weight retention. AJCN 66:1116–1124, 1997.
21. Sowers MF, Corton G, Shapiro B, et al.: Changes in bone density with lactation. JAMA 269:3130–3135, 1993.
22. Gray GE, Gray LK: Anthropometric measurements and their interpretation: Principles, practice, problems. J Am Diet Assoc 77:534–538, 1980.
23. Block G, Hartman AM, Dresser CM, et al.: A data-based approach to diet questionnaire design and testing. Am J Epidemiol 124:453–469, 1986.
24. Sallis JF, Haskell WL, Wood PD, et al.: Physical activity assessment methodology in the five-city project. Am J Epidemiol 121:91–106, 1985.
25. Parham ES, Astrom MF, King SH: The association of pregnancy weight gain with the mother's postpartum weight. J Am Diet Assoc 90:550–554, 1990.
26. Keppel KG, Taffel SM: Pregnancy-related weight gain and retention: Implications of the 1990 Institute of Medicine guidelines. Am J Public Health 83:1100–1103, 1993.
27. Parker JD, Abrams B: Differences in postpartum weight retention between black and white mothers. Obstet Gynecol 81:768–774, 1993.
28. Billewicz WZ, Thomson AM: Body weight in parous women. Brit J Prev Soc Med 24:97–104, 1970.