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Association of Fewer Hours of Sleep at 6 Months Postpartum with Substantial Weight Retention at 1 Year Postpartum

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Abstract

Shorter sleep duration is linked to obesity, coronary artery disease, and diabetes. Whether sleep deprivation during the postpartum period affects maternal postpartum weight retention remains unknown. This study examined the association of sleep at 6 months postpartum with substantial postpartum weight retention (SPPWR), defined as 5 kg or more above pregravid weight at 1 year postpartum. The authors selected 940 participants in Project Viva who enrolled during early pregnancy from 1999 to 2002. Logistic regression models estimated odds ratios of SPPWR for sleep categories, controlling for sociodemographic, prenatal, and behavioral attributes. Of the 940 women, 124 (13%) developed SPPWR. Sleep distributions were as follows: 114 (12%) women slept ≥ 5 hours/day, 280 (30%) slept 6 hours/day, 321 (34%) slept 7 hours/day, and 225 (24%) slept ≤ 8 hours/day. Adjusted odds ratios of SPPWR were 3.13 (95% confidence interval (CI): 1.42, 6.94) for ≤ 5 hours/day, 0.99 (95% CI: 0.50, 1.97) for 6 hours/day, and 0.94 (95% CI: 0.50, 1.78) for ≥ 8 hours/day versus 7 hours/day ($p = 0.012$). The adjusted odds ratio for SPPWR of 2.05 (95% CI: 1.11, 3.78) was twofold greater ($p = 0.02$) for a decrease in versus no change in sleep at 1 year postpartum. Sleeping ≤ 5 hours/day at 6 months postpartum was strongly associated with retaining ≥ 5 kg at 1 year postpartum. Interventions to prevent postpartum obesity should consider strategies to attain optimal maternal sleep duration.

Keywords

cohort studies; obesity; postpartum period; pregnancy; prospective studies; sleep; weight gain; women's health

Sleep patterns have been linked to weight gain, development of obesity and chronic disease, and mortality in adults. Both shorter and extended sleep have been linked to higher mortality rates in men and women (1,2). Sleep curtailment has been associated with a higher prevalence of obesity in adults (3,4), greater weight gain in young adults (5), and development of coronary

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artery disease and diabetes in women (6-8). Conversely, extended sleep duration (>8 hours) has also been linked to greater risk of coronary artery disease in women (7) and development of type 2 diabetes in men (8). Although lower energy expenditure or underlying disease may explain why longer duration of sleep is associated with obesity, the biologic mechanism for fewer hours of sleep and obesity is more elusive. Persistent sleep deprivation results in physiologic changes, including release of the adipocyte hormones leptin and ghrelin, which stimulate appetite, or other stress hormones such as cortisol, which may lead to overeating and subsequent obesity (9,10). Major alterations of glucose tolerance occur during sleep, and sleep quality has been shown to markedly affect glucose utilization (11).

The first postpartum year is characterized by dramatic alterations in sleep patterns for women (12). Substantial sleep curtailment follows delivery and may persist for several weeks to months, depending on infant size and developmental attributes affecting sleep. Sleep disturbances occur most often within the first month postpartum, particularly after a first birth (12,13). Few studies have assessed the average maternal sleep time cross-sectionally or longitudinally beyond the puerperium or through the first year postpartum. Clinical studies limited to samples of fewer than 50 women have examined sleep patterns within several weeks after delivery in relation to mood, cognition, and mental health in women (12,14-16). To our knowledge, the relation of postpartum sleep patterns to other physiologic aspects of maternal health, such as postpartum weight retention, has not been reported.

This study examines the association of postpartum sleep duration with substantial postpartum weight retention, defined as a gain of 5 or more kg above preconception body weight at 1 year after delivery. The objectives were to determine the extent to which 1) shorter or longer sleep durations at 6 months postpartum are associated with substantial weight retention at 1 year postpartum, controlling for sociodemographic, prenatal, and behavioral correlates, and 2) change in sleep duration from 6 months to 1 year postpartum is associated with substantial weight retention at 1 year postpartum.

MATERIALS and METHODS

Study subjects

Subjects were participants in Project Viva, an observational, longitudinal cohort study of prenatal dietary intake and lifestyle behaviors, pregnancy outcomes, and offspring health. Women were recruited at their initial prenatal visit at one of eight urban and suburban obstetric offices in a multi-specialty group practice in eastern Massachusetts from 1999 to 2002. Eligibility criteria included fluency in English, gestational age less than 22 weeks at the initial prenatal appointment, and singleton pregnancy. A total of 2,128 women who delivered a live infant were enrolled in Project Viva. Recruitment and retention details have been summarized (17,18). All women provided informed consent, and all procedures were in accordance with the ethical standards for human subjects established by the Declaration of Helsinki (19).

Of the 2,128 women, we excluded women who smoked during or after pregnancy ($n = 105$), reported an intercurrent pregnancy between the index delivery and 1 year postpartum ($n = 159$), dropped out ($n = 82$), or were lost to follow-up ($n = 344$) at 6 months postpartum. Of the 1,438 women remaining, 1,003 completed both 6-month and 1-year postpartum assessments. We excluded nine women missing hours of sleep at both time points, 34 women missing prepregnancy or 1-year postpartum weights, and 20 women missing gestational weight gain or lactation data. The analytical sample included 940 women. The women excluded were more likely to be non-White and less educated, but age, prepregnancy body mass index, and gestational weight gain were similar.

Data collection

Participants reported sociodemographic, prenatal, and behavioral characteristics via self-administered questionnaires at in-person interviews during early pregnancy and at 6 months postpartum and via mail at 1 year postpartum. We queried women about sleep duration at 6-month and 1-year postpartum assessments. Women reported their prepregnancy weight at the first prenatal visit and their current weight at 1 year postpartum via mailed questionnaires. We assessed duration of exclusive breastfeeding at 6 months postpartum and any breastfeeding at 1 year postpartum. We abstracted maternal prenatal and infant newborn characteristics from medical records.

Substantial postpartum weight retention

We defined weight retention at 1 year postpartum as the difference between self-reported weight at 12 months after delivery (mean = 13.2 (standard deviation (SD): 1.1) months) and self-reported prepregnancy weight. Postpartum weight retention was dichotomized as either substantial (≥ 5 kg; SPPWR) or not substantial (< 5 kg; not SPPWR) at 1 year postpartum as a clinically relevant endpoint that affects 14–20 percent of women in previous studies (20).

To determine the reporting error using self-reported pre-pregnancy weight, we compared the weights for 170 participants who had clinic visit measurements recorded within 3 months of their last menstrual period for the index pregnancy with self-reported prepregnancy weight at the first trimester visit. The correlation coefficient between the two weights was 0.99, with underreporting of prepregnancy weight averaging 1 kg. Correlation coefficients and reporting error did not differ by maternal race/ethnicity or gestational age at enrollment into the study.

Because weights before and 1 year after delivery were both self-reported, estimates of 1-year postpartum weight retention should maintain the rank order of individuals for actual weight change, assuming that the underreporting bias did not vary over time within an individual. Thus, by dichotomizing the variable for postpartum weight retention, we should have minimized any potential bias from self-report.

For the 786 women with measured weights at 6 months postpartum, we calculated weight loss from delivery to 6 months postpartum and from 6 months to 1 year postpartum.

Postpartum sleep duration

At 6 months postpartum and at 1 year postpartum, women reported hours of sleep within a 24-hour period, as well as self-perception of their sleep adequacy (adequate or inadequate). Two questions were posed: 1) “In the past month, how many hours of sleep do you get in an average 24-hour period?” and 2) “In the past month, do you feel that you are getting enough sleep?” The responses were integers for hours of sleep and were categorized into one of four groups (≤ 5 , 6, 7, and ≥ 8 hours per day) at each time period—6 months and 1 year postpartum. These categories are consistent with studies of nonpregnant adults (2,4,8,21). We selected 7 hours/day as the referent category because previous studies found that fewer than 7 hours of sleep were directly associated with mortality (2) and obesity (4). Change in sleep duration was defined as the difference between hours reported at 1 year and 6 months postpartum. The three categories included decrease, no change (referent group), or increase in hours of sleep per 24 hours.

Other covariates

We abstracted weight measurements obtained at visits to prenatal health-care providers from medical records. Women reported both prepregnancy weight and height during early pregnancy, and these were used to calculate body mass index (weight (kg)/height (m)²). Prepregnancy body mass index was categorized as normal weight (< 26), over-weight (26–

29.9), and obese weight (>29) on the basis of Institute of Medicine guidelines (22). The last measured weight before delivery (from prenatal visit) was used to estimate gestational weight gain, defined as the difference between the last measured weight during pregnancy and the self-reported prepregnancy weight. We categorized gestational weight gain as inadequate, adequate, or excessive on the basis of Institute of Medicine recommendations of 12.5–18 kg, 11.5–16 kg, 7–11.5 kg, and 6–11.5 kg for the prepregnancy body mass index categories <19.8 , 19.8–26.0, 26.1–29.0, and >29.0 , respectively (22).

Sociodemographic variables self-reported during pregnancy included the following: age, ≤ 24 , 25–34, or ≥ 35 years; race/ethnicity, Black, White, Hispanic, or other; parity before the index pregnancy, nulliparous, primiparous, or multiparous; marital status, married/cohabitating or single (never married/divorced/separated/widowed, other); education, some college or less, 4-year college graduate, or postgraduate; and household income, $<\$40,000$, $\$40,000$ – $\$70,000$, $>\$70,000$, or don't know/missing.

We also abstracted maternal pregnancy complications and neonatal outcomes from medical records. The categories for blood pressure status are preeclampsia, normotensive, chronic hypertension, or missing (23) and for glycemic status are gestational diabetes mellitus, impaired glucose tolerance, normoglycemia, or missing according to American Diabetes Association criteria (24). For neonates, we calculated birth weight for gestational age z scores to derive size for gestational age (25) and categorized them as average for gestational, small for gestational (<10 th percentile), and large for gestational (>90 th percentile) age. Preterm birth was <37 weeks, and a term birth was ≥ 37 weeks' gestation.

During in-person visits at 6 months postpartum, participants completed questionnaires regarding their current employment, lifestyle behaviors, and postpartum depression. We categorized employment as ≥ 35 hours/week full-time, 25–34 hours/week part-time, <25 hours/week part-time, or not employed. Women reported information about intentional dieting and weight loss, dietary intake, and physical activity/inactivity (television and video viewing) levels. We assessed dietary intake with a validated, brief food frequency questionnaire that included 21 questions about quantities of foods and food groups (26–28). Daily dietary intakes of energy, fat, carbohydrate, fiber (quartiles), and other nutrients were calculated by use of the Harvard Nutrient Database (27,28). Energy adjustment was achieved via the nutrient residual method (29). We assessed physical activity and inactivity on the basis of the leisure-time activity section of the Physical Activity Scale for the Elderly (30). We modified these questions for the Project Viva postpartum cohort by asking women to recall the average hours/week of each activity over the previous month instead of the previous 7 days. The physical activity measure has been associated with postpartum weight retention (31). We assessed maternal postpartum depression with the Edinburgh Postpartum Depression Scale and dichotomized scores ≥ 13 as depression or <13 as no depression (32).

We categorized duration of exclusive breastfeeding at 6 months postpartum as 0– <1 , 1– <3 , 3– <6 , or ≥ 6 months and any breastfeeding at 1 year postpartum as 0– <1 , 1– <3 , 3– <6 , 6– <9 , or 9– ≥ 12 months.

Statistical methods

Preliminary analyses involved description of participant characteristics using means and standard deviations for age, sleep duration, and postpartum weight retention. We also examined the mean for postpartum weight retention and other maternal characteristics across categories of sleep duration at 6 months postpartum using analysis of variance. We described frequency distributions by number and percent for the sleep duration categories by SPPWR and used chi-square statistics to assess the overall association for levels of maternal and infant characteristics with SPPWR. We calculated odds ratios and 95 percent confidence intervals for each level of

a given characteristic in relation to a selected referent group. *p* values were obtained from two-sided tests (significance of <0.05).

Multivariable logistic regression models were used to evaluate the association between sleep duration and SPPWR. Covariables associated with SPPWR based on bivariate (unadjusted) analyses were included in multivariable models to control for confounding and to assess their individual association with SPPWR. A parsimonious model was developed by selecting covariables on the basis of their impact on odds ratios of SPPWR for sleep duration categories as well as *p* values. Infant prematurity and size for gestational age, length of gestation, gestational hypertension, gestational glycemia, income, employment, depression status, and exclusive breastfeeding were not retained in the adjusted models, because they were either not associated with SPPWR independent of sleep duration, or their removal from the model had minimal influence on the odds of SPPWR associated with sleep duration. Of postpartum behavioral attributes, we identified duration of any breastfeeding at 1 year and dietary fiber intake as potential confounders. Among dietary constituents, fiber intake was most strongly associated with both SPPWR and sleep duration.

We constructed three logistic regression models to demonstrate the separate impact of sociodemographic, clinical prenatal, and postpartum behavioral attributes on the odds ratios for SPPWR among sleep duration categories (models 1, 2, and 3). To a fourth model, we added change in sleep duration. Models 3 and 4 were based on 865 women because of missing dietary and physical activity data (*n* = 75). Goodness-of-fit for the logistic regression models was assessed by log likelihood.

RESULTS

For the 940 participants, the mean age was 33.0 (SD: 4.7) years, prepregnancy body mass index was 24.3 (SD: 4.7) kg/m², and 22 percent classified themselves as other than White. Reflective of a generally employed and insured managed-care population, relatively few women had less than a college degree (24 percent) or had annual household incomes below \$40,000 (10 percent).

At 1 year postpartum, the mean weight retention was 0.8 (SD: 4.5) kg (range: -17.3 to 25.5), and 124 (13 percent) had SPPWR. The mean for hours of sleep per 24-hour period at 6 months postpartum was 6.7 (SD: 1.2) hours/day. Sleep duration categories were distributed as follows: ≤5 hours/day (*n* = 114, 12 percent); 6 hours/day (*n* = 280, 30 percent); 7 hours/day (*n* = 321, 34 percent); and ≥8 hours/day (*n* = 225, 24 percent). Women across sleep categories had similar gestational weight gains (15 kg), but those who slept ≤5 hours/day had a slightly higher mean prepregnancy body mass index (25 vs. 24 kg/m²) and were more likely to be multiparous than women who slept ≥7 hours/day (data not shown).

The mean for hours of sleep per 24-hour period at 1 year postpartum was 7.0 (SD: 1.1) hours/day. More women reported longer sleep durations at 1 year than at 6 months postpartum with fewer women, 45 (5 percent) and 256 (27 percent) reporting ≤5 hours/day or 6 hours/day, respectively, and greater proportions, 356 (38 percent) and 283 (30 percent) reporting 7 hours/day or ≥8 hours/day, respectively.

Among 786 women, the net weight loss averaged 2 kg per month for the first 6 months and 0.3 kg per month for the subsequent 6 months postpartum, with a similar trajectory of weight loss among prepregnancy body mass index groups. The mean weight loss from 6 months to 1 year postpartum was -1.5 (SD: 3.0) kg in normal weight and -1.9 (SD: 4.7) kg in overweight women. The mean weight loss between 6 months and 1 year postpartum was lower with shorter sleep duration: -1.2 (SD: 3.2) kg for ≤5 hours/day, -1.7 (SD: 3.5) kg for 6 hours/day, -1.5 (SD: 3.4) kg for 7 hours/day, and -1.8 (SD: 3.7) kg for ≥8 hours/day.

The mean for 1-year postpartum weight retention across categories of sleep duration at 6 months postpartum (figure 1) shows a J-shaped relation, with a mean of 1.6 (95 percent confidence interval (CI): 0.7, 2.5) kg for ≤ 5 hours/day, 0.3 (95 percent CI: -0.2, 0.8) kg for 6 hours/day, 0.8 (95 percent CI: 0.3, 1.3) kg for 7 hours/day, and 1.0 (95 percent CI: 0.4, 1.7) kg for ≥ 8 hours/day. In unadjusted logistic models (table 1), shorter sleep duration (≤ 5 hours/day vs. 7 hours/day) at 6 months postpartum (odds ratio (OR) 3.08, 95 percent CI: 1.76, 5.38) and at 1 year postpartum (OR = 3.38, 95 percent CI: 1.66, 6.86) and a reduction in sleep duration from 6 months to 1 year postpartum (for decrease vs. no change: OR = 1.94, 95 percent CI: 1.19, 3.17) were each directly associated with SPPWR. The perception of sleep adequacy was not associated with SPPWR.

Table 2 shows the maternal sociodemographic and prenatal characteristics examined as potential confounders of the sleep and SPPWR association. The characteristics, in order of magnitude of their direct associations with SPPWR, were age less than 25 years, single status, less education, lower household income, non-White race/ethnicity, excessive gestational weight gain, gestational hypertension, obesity before pregnancy, and multiparity.

The maternal characteristics at 6 months postpartum most strongly associated with SPPWR in unadjusted analyses (table 3) included higher physical inactivity (television/ video viewing), consuming lower levels of dietary fiber, dieting intentionally, shorter duration of exclusive breastfeeding, and postpartum depression. Women with a shorter duration of any breastfeeding through 1 year postpartum were twice as likely to have SPPWR.

In multivariable models (table 4), we examined the association of sleep duration at 6 months postpartum and SPPWR after taking into account maternal sociodemographic, prenatal, and behavioral attributes. The sociodemographic and prenatal attributes moderately confounded the crude odds ratio for < 5 hours/day of sleep and SPPWR (un-adjusted OR = 3.08 vs. ORs = 2.24 and 2.20, respectively, from models 1 and 2). In model 3, the adjusted odds ratio for sleeping ≤ 5 hours/day versus 7 hours/day was strengthened from 2.20 to 2.32 (95 percent CI: 1.14, 4.71) with the addition of postpartum behaviors (breastfeeding at 1 year, dietary fiber intake, physical inactivity). The crude association of ≥ 8 hours/day of sleep with SPPWR was abolished with adjustment for potential confounders (models 1, 2, and 3). In model 4, the addition of change in sleep duration between 6 months and 1 year postpartum strengthened the association between shorter sleep duration (≤ 5 hours/day vs. 7 hours/day) at 6 months postpartum and SPPWR (OR 3.13, 95 percent CI 1.42, 6.94) with little influence on the other sleep duration category estimates. A direct association with SPPWR was also observed for a decrease in sleep between 6 months and 1 year postpartum (OR 2.05, 95 percent CI: 1.11, 3.78) versus no change in hours/day of sleep duration adjusted for covariables.

DISCUSSION

This study found that women reporting shorter sleep duration (≤ 5 hours within a 24-hour period) at 6 months postpartum were 2.3 times more likely to retain at least 5 kg at 1 year independent of potential confounders including maternal sociodemographics, prepregnancy body mass index, gestational weight gain, parity, and postpartum behaviors. Furthermore, the association of ≤ 5 hours per day of sleep at 6 months postpartum and substantial weight retention was strengthened to a threefold greater risk after controlling for subsequent change in sleep duration from 6 months to 1 year postpartum. Women who reported a reduction in hours of sleep at 1 year postpartum were two times more likely to have substantial postpartum weight retention. Longer sleep duration (≥ 8 hours/24-hour period) was not associated with substantial postpartum weight retention independent of other maternal risk factors. Our findings indicate that postpartum sleep deprivation reported at 6 months postpartum and a decrease in sleep

duration in the subsequent 6 months are each associated with substantial weight retention at 1 year postpartum.

Our findings that several maternal sociodemographic, prenatal, and behavioral attributes were associated with substantial postpartum weight retention are consistent with previous studies, except for the higher risk associated with multiparity in our cohort. Numerous studies have reported that gestational weight gain (33-40) and pregravid obesity (20,39,41,42) strongly influence postpartum weight retention. Other maternal attributes less consistently or only weakly associated with average or substantial postpartum weight retention include primiparity, demographics (low income, educational level), and modifiable lifestyle changes such as lactation, employment outside the home, physical activity, and dietary intake (31,34,38,40, 43,44). Sleep curtailment may be another important influence on postpartum weight changes associated with childbearing. Potentially, postpartum sleep deprivation that persists for several months after delivery may promote higher levels of gestational weight retention in women during the postpartum period. Total sleep time estimated by polysomnography (subjects, $n < 30$) averages 372 minutes at 1 month and 390–420 minutes at 3 months postpartum (12) as compared with 6.7 hours in our study.

The biologic plausibility for our findings that sleep influences weight changes has been demonstrated among adults in general. In men and women, both restricted and extended sleep durations have been associated with greater risk of obesity and chronic disease in epidemiologic studies (6-8). Experimental studies provide evidence in humans for a biologic mechanism to explain these associations. In a randomized trial, restriction of the amount of sleep for 2 days resulted in changes in the levels of certain hormones controlling appetite (9). Sleep restriction reduced levels of the fat-derived hormone, leptin, and increased levels of the stomach-derived hormone, ghrelin, which have the combined effect of stimulating hunger (9). A correlation was seen between the increasing ratio of ghrelin to leptin and increasing appetite. These findings support the hypothesis that sleep curtailment increases appetite and perhaps leads to obesity (3). Another explanation is that cortisol levels may be increased as a result of the stress of sleep curtailment or other unknown factors and may be the true cause of the increased hunger.

The potential limitations of our study include lack of data on sleep duration before and during pregnancy and that we were unable to examine sleep duration at within 1 month postpartum when sleep disturbance is most intense. Our finding that the association of postpartum sleep deprivation and substantial weight retention 1 year after delivery was not due to differences in gestational weight gain or prepregnancy obesity supports the hypothesis that sleep duration in the postpartum period may influence weight changes. However, we cannot determine whether the greater weight retention is related to shorter sleep duration that preceded pregnancy. Our study also did not collect data on sleep patterns to determine whether the number of sleep intervals in addition to the total time may be important to maternal weight change. We could not ascertain in this study whether sleep deprivation reported at 6 months postpartum had persisted since the early postpartum period. Self-report of prepregnancy and postpartum weights and missing behavioral data for 8 percent of the sample are limitations. The high educational level and mostly White participants may limit the generalizability of our findings.

The strengths of our study that outweigh the limitations include its prospective nature; examination of sociodemographic, clinical, and behavioral parameters that influence maternal postpartum weight changes; collection of weight data before, during, and after pregnancy; and self-reported sleep duration at 6 months and again at 1 year postpartum in a large cohort.

Our findings are provocative in raising the question of whether changes in sleep during the postpartum period influence development of obesity in women. Our study provides evidence that sleep curtailment at 6 months postpartum is associated with substantial postpartum weight

retention at 1 year independent of gestational weight gain and pregravid body mass index, the strongest predictors of weight retention (20,41), as well as sociodemographic and postpartum behavioral attributes. The association of ≤ 5 hours/day of sleep with substantial weight retention is similar in magnitude to and, therefore, in relative importance to the association observed for gestational weight gain above the Institute of Medicine recommendations. Another important finding is that decrease in sleep duration between 6 and 12 months postpartum was associated with greater weight retention. These findings open the possibility that modifying sleep duration during the postpartum period could help to prevent postpartum weight retention, but intervention studies are required. Additional research is necessary to identify predictors of shortened postpartum sleep duration, to examine whether sleep patterns influence postpartum weight changes, and to determine whether sleep duration during the early postpartum period (e.g., 4–6 weeks) has a similar impact on weight retention.

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Abbreviations

CI	confidence interval
OR	odds ratio
SD	standard deviation
SPPWR	substantial postpartum weight retention

REFERENCES

1. Kripke DF, Garfinkel L, Wingard DL, et al. Mortality associated with sleep duration and insomnia. *Arch Gen Psychiatry* 2002;59:131–6. [PubMed: 11825133]
2. Patel SR, Ayas NT, Malhotra MR, et al. A prospective study of sleep duration and mortality risk in women. *Sleep* 2004;27:440–4. [PubMed: 15164896]
3. Flier JS, Elmquist JK. A good night's sleep: future antidote to the obesity epidemic? *Ann Intern Med* 2004;141:885–6. [PubMed: 15583232]
4. Gangwisch JE, Malaspina D, Boden-Albala B, et al. Inadequate sleep as a risk factor for obesity: analyses of the NHANES I. *Sleep* 2005;28:1289–96. [PubMed: 16295214]
5. Hasler G, Buysse DJ, Klaghofer R, et al. The association between short sleep duration and obesity in young adults: a 13-year prospective study. *Sleep* 2004;27:661–6. [PubMed: 15283000]
6. Ayas NT, White DP, Al Delaimy WK, et al. A prospective study of self-reported sleep duration and incident diabetes in women. *Diabetes Care* 2003;26:380–4. [PubMed: 12547866]
7. Ayas NT, White DP, Manson JE, et al. A prospective study of sleep duration and coronary heart disease in women. *Arch Intern Med* 2003;163:205–9. [PubMed: 12546611]
8. Yaggi HK, Araujo AB, McKinlay JB. Sleep duration as a risk factor for the development of type 2 diabetes. *Diabetes Care* 2006;29:657–61. [PubMed: 16505522]
9. Spiegel K, Tasali E, Penev P, et al. Brief communication: sleep curtailment in healthy young men is associated with decreased leptin levels, elevated ghrelin levels, and increased hunger and appetite. *Ann Intern Med* 2004;141:846–50. [PubMed: 15583226]
10. Copinschi G. Metabolic and endocrine effects of sleep deprivation. *Essent Psychopharmacol* 2005;6:341–7. [PubMed: 16459757]
11. Scheen AJ, Van Cauter E. The roles of time of day and sleep quality in modulating glucose regulation: clinical implications. *Horm Res* 1998;49:191–201. [PubMed: 9550124]
12. Lee KA, Zaffke ME, McEnany G. Parity and sleep patterns during and after pregnancy. *Obstet Gynecol* 2000;95:14–18. [PubMed: 10636494]

13. Shinkoda H, Matsumoto K, Park YM. Changes in sleep-wake cycle during the period from late pregnancy to puerperium identified through the wrist actigraph and sleep logs. *Psychiatry Clin Neurosci* 1999;53:133–5. [PubMed: 10459670]
14. Wolfson AR, Crowley SJ, Anwer U, et al. Changes in sleep patterns and depressive symptoms in first-time mothers: last trimester to 1-year postpartum. *Behav Sleep Med* 2003;1:54–67. [PubMed: 15600137]
15. Lee KA. Alterations in sleep during pregnancy and postpartum: a review of 30 years of research. *Sleep Med Rev* 1998;2:231–42. [PubMed: 15310494]
16. Quillin SI. Infant and mother sleep patterns during 4th postpartum week. *Issues Compr Pediatr Nurs* 1997;20:115–23. [PubMed: 9423387]
17. Gillman MW, Rich-Edwards JW, Rifas-Shiman SL, et al. Maternal age and other predictors of newborn blood pressure. *J Pediatr* 2004;144:240–5. [PubMed: 14760269]
18. Oken E, Kleinman KP, Olsen SF, et al. Associations of seafood and elongated n-3 fatty acid intake with fetal growth and length of gestation: results from a US pregnancy cohort. *Am J Epidemiol* 2004;160:774–83. [PubMed: 15466500]
19. World Medical Association declaration of Helsinki. Recommendations guiding physicians in biomedical research involving human subjects. *JAMA* 1997;277:925–6. [PubMed: 9062334]
20. Gunderson EP, Abrams B. Epidemiology of gestational weight gain and body weight changes after pregnancy. *Epidemiol Rev* 1999;21:261–75. [PubMed: 10682262]
21. Taheri S, Lin L, Austin D, et al. Short sleep duration is associated with reduced leptin, elevated ghrelin, and increased body mass index. *PLoS Med* 2004;1:e62. [PubMed: 15602591]
22. Institute of Medicine. Nutrition during pregnancy. National Academy of Sciences; Washington, DC: 1990.
23. Report of the National High Blood Pressure Education Program Working Group on High Blood Pressure in Pregnancy. *Am J Obstet Gynecol* 2000;183(suppl):S1–22.
24. American Diabetes Association. Gestational diabetes mellitus. *Diabetes Care* 2004;27(suppl 1):S88–90. [PubMed: 14693936]
25. Oken E, Kleinman K, Rich-Edwards JW, et al. A nearly continuous measure of birth weight for gestational age using a United States national reference. *BMC Pediatr* 2003;3:6. [PubMed: 12848901]
26. Rifas-Shiman SL, Willett WC, Lobb R, et al. PrimeScreen, a brief dietary screening tool: reproducibility and comparability with both a longer food frequency questionnaire and biomarkers. *Public Health Nutr* 2001;4:249–54. [PubMed: 11299098]
27. Willett WC, Sampson L, Stampfer MJ, et al. Reproducibility and validity of a semiquantitative food frequency questionnaire. *Am J Epidemiol* 1985;122:51–65. [PubMed: 4014201]
28. Fung TT, Hu FB, Yu J, et al. Leisure-time physical activity, television watching, and plasma biomarkers of obesity and cardiovascular disease risk. *Am J Epidemiol* 2000;152:1171–8. [PubMed: 11130623]
29. Willett, W. Nutritional epidemiology. Oxford University Press; Oxford, United Kingdom: 1998.
30. Washburn RA, Smith KW, Jette AM, et al. The Physical Activity Scale for the Elderly (PASE): development and evaluation. *J Clin Epidemiol* 1993;46:153–62. [PubMed: 8437031]
31. Oken E, Taveras EM, Popoola FA, et al. Television, walking, and diet: associations with postpartum weight retention. *Am J Prev Med* 2007;32:305–11. [PubMed: 17383561]
32. Cox JL, Holden JM, Sagovsky R. Detection of postnatal depression. Development of the 10-item Edinburgh Postnatal Depression Scale. *Br J Psychiatry* 1987;150:782–6. [PubMed: 3651732]
33. Greene GW, Smiciklas-Wright H, Scholl TO, et al. Postpartum weight change: how much of the weight gained in pregnancy will be lost after delivery? *Obstet Gynecol* 1988;71:701–7. [PubMed: 3357658]
34. Olson CM, Strawderman MS, Hinton PS, et al. Gestational weight gain and postpartum behaviors associated with weight change from early pregnancy to 1 y postpartum. *Int J Obes Relat Metab Disord* 2003;27:117–27. [PubMed: 12532163]
35. Kac G, Benicio MH, Velasquez-Melendez G, et al. Gestational weight gain and prepregnancy weight influence postpartum weight retention in a cohort of Brazilian women. *J Nutr* 2004;134:661–6. [PubMed: 14988464]

36. Gunderson EP, Abrams B, Selvin S. The relative importance of gestational gain and maternal characteristics associated with the risk of becoming overweight after pregnancy. *Int J Obes Relat Metab Disord* 2000;24:1660–8. [PubMed: 11126221]
37. Gore SA, Brown DM, West DS. The role of postpartum weight retention in obesity among women: a review of the evidence. *Ann Behav Med* 2003;26:149–59. [PubMed: 14534032]
38. Ohlin A, Rossner S. Maternal body weight development after pregnancy. *Int J Obes* 1990;14:159–73. [PubMed: 2341224]
39. Keppel KG, Taffel SM. Pregnancy-related weight gain and retention: implications of the 1990 Institute of Medicine guidelines. *Am J Public Health* 1993;83:1100–3. [PubMed: 8342716]
40. Schauburger CW, Rooney BL, Brimer LM. Factors that influence weight loss in the puerperium. *Obstet Gynecol* 1992;79:424–9. [PubMed: 1738527]
41. Gunderson EP, Abrams B, Selvin S. Does the pattern of postpartum weight change differ according to pregravid body size? *Int J Obes Relat Metab Disord* 2001;25:853–62. [PubMed: 11439300]
42. Billewicz WZ. Body weight in parous women. *Br J Prev Soc Med* 1970;24:97–104. [PubMed: 5431074]
43. Ohlin A, Rossner S. Trends in eating patterns, physical activity and socio-demographic factors in relation to postpartum body weight development. *Br J Nutr* 1994;71:457–70. [PubMed: 8011603]
44. Janney CA, Zhang D, Sowers M. Lactation and weight retention. *Am J Clin Nutr* 1997;66:1116–24. [PubMed: 9356528]

FIGURE 1.

Mean (95% confidence interval) postpartum weight retention for categories of sleep duration at 6 months postpartum, Project Viva, 1999–2003.

Frequencies and unadjusted associations of sleep duration characteristics with substantial postpartum weight retention at 1 year postpartum, Project Viva, 1999–2003

TABLE 1

Postpartum characteristics	Not SPPWR* (≤ 5 kg) (n = 816)		SPPWR (≥ 5 kg) (n = 124)		p value [†]	SPPWR	
	No.	%	No.	%		Unadjusted odds ratio	95% confidence interval
At 6 months postpartum							
Sleep (hours/day)					<0.001		
≤ 5	85	10	29	23		3.08	1.76, 5.38
6	254	31	26	21		0.92	0.54, 1.59
7	289	35	32	26		1.00	Referent
≥ 8	188	23	37	30	1.78	1.07, 2.95	
Perception of enough sleep							
No	440	54	68	55	0.85	1.04	0.71, 1.52
Yes	376	46	56	45	1.00	1.00	Referent
At 1 year postpartum							
Sleep (hours/day)					0.001		
≤ 5	31	4	14	11		3.38	1.66, 6.86
6	218	27	38	31		1.30	0.81, 2.09
7	314	38	42	34		1.00	Referent
≥ 8	253	31	30	24	0.89	0.54, 1.46	
Change in hours of sleep between 6 months and 1 year postpartum							
Increase	292	36	45	36	0.03	1.27	0.82, 1.97
No change	388	48	47	38	1.00	1.00	Referent
Decrease	136	17	32	26	1.94	1.19, 3.17	

* SPPWR, substantial postpartum weight retention.

† p values from global chi square.

Frequencies and unadjusted associations of maternal and infant characteristics with substantial postpartum weight retention at 1 year postpartum, Project Viva, 1999–2003

TABLE 2

Characteristics	Not SPPWR* (<5 kg) ($n = 816$)		SPPWR (≥ 5 kg) ($n = 124$)		p value [†]	SPPWR	
	No.	%	No.	%		Unadjusted odds ratio	95% confidence interval
Sociodemographic							
Age (years)					<0.001		
<25	23	3	24	19		9.09	4.83, 17.11
25–34	514	63	59	48		1.00	Referent
≥ 35	279	34	41	33		1.28	0.84, 1.96
Race					<0.001		
White	657	81	75	60		1.00	Referent
Black	64	8	24	19		3.29	1.94, 5.56
Hispanic	37	5	10	8		2.37	1.13, 4.95
Other	58	7	15	12		2.27	1.22, 4.19
Education					<0.001		
Some college or less	174	21	48	39		3.97	2.34, 6.74
College degree (4 years)	311	38	53	43		2.45	1.47, 4.10
Postgraduate degree	331	41	23	19		1.00	Referent
Income (\$)					<0.001		
<40,000	66	8	24	19		3.36	1.97, 5.76
40,000–<70,000	158	19	28	23		1.64	1.01, 2.66
$\geq 70,000$	555	68	60	48		1.00	Referent
Don't know/missing	37	5	12	10		3.00	1.49, 6.06
Marital status					<0.001		
Married/cohabitating	795	97	104	84		1.00	Referent
Single	21	3	20	16		7.28	3.82, 13.88
Clinical prenatal							
Parity before index birth					0.001		

Characteristics	Not SPPWR* (<5 kg) ($n = 816$)		SPPWR (≥ 5 kg) ($n = 124$)		<i>p</i> value [†]	SPPWR	
	No.	%	No.	%		Unadjusted odds ratio	95% confidence interval
Nulliparous	365	45	74	60		1.21	0.72, 2.02
Primiparous	320	39	28	23		0.52	0.29, 0.94
Multiparous	131	16	22	18		1.00	Referent
Prepregnancy body mass index (IOM*)					<0.001		
Normal (<26 kg/m ²)	628	77	75	60		1.00	Referent
Overweight (26–29 kg/m ²)	92	11	21	17		1.91	1.12, 3.25
Obese (>29 kg/m ²)	96	12	28	23		2.44	1.51, 3.96
Gestational weight gain (IOM)					<0.001		
Inadequate	129	16	4	3		0.38	0.13, 1.10
Adequate	316	39	26	21		1.00	Referent
Excessive	371	45	94	76		3.08	1.95, 4.88
Maternal hypertension					0.007		
Chronic hypertension	14	2	3	2		1.57	0.44, 5.56
Gestational hypertension	49	6	18	15		2.69	1.51, 4.81
Preeclampsia	22	3	4	3		1.33	0.45, 3.95
None	718	88	98	79		1.00	Referent
Missing	13	2	1	1			
Maternal glycemic status					0.15		
Gestational diabetes mellitus	39	5	2	2		0.35	0.08, 1.49
Impaired glucose tolerance	84	10	17	14		1.39	0.80, 2.45
Normal glucose tolerance	689	84	100	81		1.00	Referent
Missing	4	0	5	4			
Infant outcomes							
Preterm (<37 weeks)	48	6	11	9	0.20	1.56	0.79, 3.09
Term (≥ 37 weeks)	768	94	113	91		1.00	Referent
SGA* infant	29	4	9	7	0.05	2.12	0.98, 4.60
AGA* or LGA* infant	786	96	115	93		1.00	Referent

* SPPWR, substantial postpartum weight retention; IOM, Institute of Medicine; SGA, small for gestational age; AGA, average for gestational age; LGA, large for gestational age.

† p values from global chi square.

Frequencies and unadjusted associations of maternal postpartum behaviors with substantial postpartum weight retention at 1 year postpartum, Project Viva, 1999–2003

TABLE 3

Postpartum characteristics	Not SPPWR* (≤ 5 kg) (n = 816)		SPPWR (≥ 5 kg) (n = 124)		p value [†]	SPPWR	
	No.	%	No.	%		Unadjusted odds ratio	95% confidence interval
At 6 months postpartum							
Employment (hours/week)					0.82		
None	298	37	41	33		1.00	Referent
Part-time (<25)	168	21	25	20		1.08	0.64, 1.84
Part-time (25–34)	109	13	18	15		1.20	0.66, 2.18
Full-time (≥ 35)	234	29	40	32		1.24	0.78, 1.98
Missing	7	1	0	0			
Physical inactivity (quartiles)					0.007		
1 (lowest)	206	25	19	15		1.00	Referent
2	137	17	13	10		1.03	0.49, 2.15
3	227	28	36	29		1.72	0.96, 3.09
4 (highest)	190	23	42	34		2.40	1.35, 4.27
Missing	56	7	14	11			
Dietary intake fiber quartiles (g/day)					<0.001		
1 (lowest)	178	22	41	33		3.95	2.02, 7.75
2	186	23	33	27		3.04	1.53, 6.07
3	194	24	25	20		2.21	1.08, 4.52
4 (highest)	206	25	12	10		1.00	Referent
Missing	52	6	13	10			
Intentional weight loss					<0.001		
Yes	380	47	74	60		2.08	1.37, 3.18
No	385	47	36	29		1.00	Referent
Missing	51	6	14	11			
Intentional dieting					<0.001		

Postpartum characteristics	Not SPPWR* (<5 kg) ($n = 816$)		SPPWR (≥ 5 kg) ($n = 124$)		p value [†]	SPPWR	
	No.	%	No.	%		Unadjusted odds ratio	95% confidence interval
Yes	308	38	65	52		2.14	1.43, 3.22
No	457	56	45	36		1.00	Referent
Missing	51	6	14	11			
Postpartum depression score					0.03		
Yes (≥ 13)	52	6	14	11		1.98	1.06, 3.71
No (< 13)	707	87	96	77		1.00	Referent
Missing	57	7	14	11			
Exclusive breastfeeding (months)					0.009		
0–<1	260	32	55	44		1.96	1.20, 3.18
1–<3	101	12	20	16		1.83	0.99, 3.40
3–<6	196	24	21	17		0.99	0.55, 1.80
≥ 6	259	32	28	23		1.00	Referent
At 1 year postpartum							
Any breastfeeding (months)					0.14		
0–<1	132	16	27	22		1.83	1.08, 3.10
1–<3	59	7	8	6		1.21	0.54, 2.72
3–<6	140	17	26	21		1.66	0.98, 2.83
6–<9	127	16	23	19		1.62	0.93, 2.81
9– ≥ 12	358	44	40	32		1.00	Referent

* SPPWR, substantial postpartum weight retention.

[†] p values from global chi square.

Unadjusted and multivariable-adjusted odds ratios of substantial postpartum weight retention at 1 year postpartum according to categories of maternal sleep duration at 6 months and change in sleep duration from 6 to 12 months postpartum, Project Viva, 1999–2003

TABLE 4

Sleep categories	Unadjusted			Model 1*			Model 2†			Model 3‡,§			Model 4§,¶		
	Odds ratio	95% confidence interval		Odds ratio	95% confidence interval		Odds ratio	95% confidence interval		Odds ratio	95% confidence interval		Odds ratio	95% confidence interval	
Sleep duration (hours/day) at 6 months postpartum															
≤5	3.08	1.76, 5.38		2.24	1.21, 4.14		2.20	1.15, 4.21		2.32	1.14, 4.71		3.13	1.42, 6.94	
6	0.92	0.54, 1.59		0.77	0.43, 1.37		0.78	0.42, 1.42		0.83	0.43, 1.62		0.99	0.50, 1.97	
7	1.00	Referent		1.00	Referent		1.00	Referent		1.00	Referent		1.00	Referent	
≥8	1.78	1.07, 2.95		1.31	0.76, 2.26		1.13	0.64, 2.00		1.20	0.65, 2.20		0.94	0.50, 1.78	
Change in sleep (hours/day) from 6 months to 1 year postpartum															
Increase	1.27	0.82, 1.97											0.77	0.41, 1.43	
No change	1.00	Referent											1.00	Referent	
Decrease	1.94	1.19, 3.17											2.05	1.11, 3.78	

* Model 1 (*n* = 940) includes race/ethnicity, marital status, education, age, and parity.

† Model 2 (*n* = 940) includes model 1 plus prepregnancy body mass index (continuous) and gestational weight gain (Institute of Medicine categories).

‡ Model 3 (*n* = 865) includes model 2 plus behaviors (dietary fiber intake and physical inactivity at 6 months postpartum and breastfeeding duration at 1 year).

§ For models 3 and 4, there are fewer women (*n* = 865) because of incomplete information on dietary intake and physical inactivity (television/video viewing) for 75 women.

¶ Model 4 (*n* = 865) includes model 3 plus change in hours of sleep from 6 months to 1 year postpartum.