Breastfeeding After Gestational Diabetes Pregnancy

Subsequent obesity and type 2 diabetes in women and their offspring

ERICA P. GUNDERSON, PHD

Breastfeeding provides important health benefits to both women and their offspring. Health benefits of lactation for women include a lower risk of breast and ovarian cancer (1) and possibly protection against type 2 diabetes (2). For the offspring, breastfeeding confers protection against both undernutrition and overnutrition during early childhood (3) and may lower risk of developing obesity, hypertension, cardiovascular disease, and diabetes later in life (4–7). Postnatal feeding is one of several critical or sensitive developmental periods (fetal life, adiposity rebound in childhood, and adolescence) hypothesized to result in "metabolic programming" of future chronic disease risk (8,9).

In developed countries, there is a robust association between breastfeeding and a lower risk of becoming overweight during childhood and adolescence, even after accounting for maternal obesity and family lifestyle behaviors (10–13). Moreover, greater protection against childhood overweight is associated with more prolonged exclusive breastfeeding. In the U.S., the association of breastfeeding and lower risk of childhood overweight has been observed in Caucasians, but not among low-income Hispanics or African-Americans.

Fetal life is another important developmental period influencing future health. Maternal gestational diabetes mellitus (GDM) alters the intrauterine milieu for fetal development that may affect risk factors for chronic disease later in life (14). In some (15–18), but not all (19) studies, offspring of GDM mothers may be more likely to become overweight and to develop type 2 diabetes later in life. A combination of genetic, intrauterine, and postnatal factors contribute to development of childhood obesity and type 2 diabetes in the offspring of women with GDM.

Whether breastfeeding affects the future health of offspring of women with GDM is uncertain based on limited and conflicting findings from studies of Native Americans or women with diabetes during pregnancy. Furthermore, no studies that examined the relation of breastfeeding to development of obesity and diabetes in the offspring of women with GDM have controlled for the intrauterine metabolic environment.

Lactation may also confer health benefits to women with a history of GDM. Lactation improves glucose tolerance in the early postpartum period, but it is unclear whether future risk of type 2 diabetes is reduced.

Here, the evidence for the general population is critically examined for an association of breastfeeding with the risk of obesity and its biological plausibility. Next, evidence is examined among offspring of women with GDM that breastfeeding influences their risk of overweight and type 2 diabetes. Lastly, lactation's effect on maternal postpartum glucose tolerance and prevention of type 2 diabetes among women with and without previous GDM is examined. Given the equivocal findings for GDM women and their offspring, further research is recommended.

From the Epidemiology and Prevention Section, Division of Research, Kaiser Permanente, Oakland, California.

Address correspondence and reprint requests to Erica P. Gunderson, PhD, Epidemiologist, Research Scientist II, Epidemiology and Prevention Section, Division of Research, Kaiser Permanente, 2000 Broadway, Oakland, CA 94612. E-mail: epg@dor.kaiser.org.

Received for publication 28 March 2006 and accepted in revised form 3 October 2006.

This article is based on a presentation at a symposium. The symposium and the publication of this article were made possible by an unrestricted educational grant from LifeScan, Inc., a Johnson & Johnson company.

Abbreviations: GDM, gestational diabetes mellitus.

A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

DOI: 10.2337/dc07-s210

BREASTFEEDING AND DEVELOPMENT OF OVERWEIGHT IN OFFSPRING IN THE GENERAL POPULATION —

Breastfeeding is recommended as the preferred method of infant feeding for the first year of life or longer, and exclusive breastfeeding is recommended for the first 6 months of life (20). The Institute of Medicine defines exclusive breastfeeding as an infant's consumption of human milk with no supplementation of any type (no water, juice, nonhuman milk, or foods) except for vitamins, minerals, and medications (21). In the U.S., breastfeeding initiation rates have increased steadily since 1990, but exclusive breastfeeding rates have shown little or no increase over the same period (22). Exclusive breastfeeding at 6 months declined from 18 to 12% between 1981 and 1997 (22) and by 2003 had reached 17% (23). From 1988 to 1994, the prevalence of overweight (defined as BMI >95th percentile) in U.S. youth aged 6–17 years was 11% (24). By 1999–2002, the prevalence had increased to 16% of youth aged 6–19 years (25). Given that weight tracks from early life into adult life (26–28) and that childhood weight gain and obesity have been linked to chronic diseases later in life (29,30), breastfeeding may be an important contributor to prevention of obesity and its sequelae.

Breastfeeding and overweight in early childhood and adolescence

Breastfeeding protects against becoming overweight and obese during childhood and adolescence, as well as underweight during infancy and childhood (3). Because breastfeeding decreases the variability in BMI within a population, comparison of the means does not distinguish the effects of breastfeeding on infant growth (3). The prevalence of overweight or obesity is the outcome measure used to evaluate the effects of breastfeeding in the population.

Three reviews of published studies, one quantitative review, one meta-analysis, and one systematic review, all

concluded that breastfeeding reduces the risk of overweight in children and adolescents (11–13). Of six additional studies not included in these reviews, four reported protective associations adjusted for covariates (31–34), one found that adjustment for paternal attributes abolished the association (35), and another had mixed findings (36). Overall, 21 studies that included 100 or more subjects per feeding group and examined overweight or obesity in children at least 3 years of age provide the most informative estimates (3,10,31–39). In 17 of these 21 studies, breastfeeding resulted in a 20–50% lower risk of overweight depending on duration of breastfeeding and degree of supplementation. Adjustment for maternal obesity, infant birth weight, and other confounders generally attenuated, but did not abolish, the association. In a meta-analysis of 17 studies, Harder et al. (13) found a strong dose-response relationship between increasing duration of months of breastfeeding and 4% reduction in risk of overweight per month of breastfeeding unadjusted for potential confounders.

A quantitative review of 61 studies focusing on infant feeding and obesity through the life course concluded that breastfeeding moderately reduced the risk of overweight (12). Among 28 studies reporting odds ratios (ORs), breastfeeding was associated with a lower risk of obesity, compared with formula feeding (OR 0.87, 95% CI 0.85–0.89). A stronger inverse association between breastfeeding and obesity was found in 11 studies with <500 subjects (OR 0.43, 95% CI 0.33–0.55). The consistency of the association across all age-groups, from infancy to adulthood, suggests that early breastfeeding may have lasting protective effects independent of dietary and physical activity patterns later in life (12).

The association of breastfeeding with child overweight may vary by race/ethnicity and maternal attributes such as smoking, pregravid obesity, and diabetes during pregnancy. In two studies of low-income U.S. children aged 4 years (73,000 in Ohio and 177,000 across the U.S.), breastfeeding was associated with a lower risk of child overweight and obesity in non-Hispanic white children, but no relationship was found among African-American or Hispanic children (3,31). In mothers who smoked during pregnancy, breastfeeding was not found to reduce risk of obesity in the offspring (35). This may be because maternal smoking during pregnancy retards fetal growth, which then leads to rapid postnatal growth and higher risk of obesity in the offspring (31). Disparities by race/ethnicity group and maternal attributes (i.e., smoking) in the association of breastfeeding with child overweight warrant further investigation.

To our knowledge, maternal GDM during pregnancy was examined as a potential confounder in only one study of breastfeeding and risk of overweight in the general population (31). Maternal GDM was associated with a 30% higher risk of obesity in adolescent offspring after adjustment for duration of breastfeeding and other potential confounders, but no data were presented to determine whether breastfeeding influenced the risk of overweight specifically among the offspring of women with GDM (17).

Influence of maternal obesity on breastfeeding and overweight in offspring

Maternal obesity represents genetic and intrauterine and postnatal environmental influences on the development of offspring (14). Maternal pregravid obesity is correlated with fetal macrosomia and subsequent obesity in the offspring (40). In most studies, the reduction in risk of overweight in childhood with breastfeeding has remained after adjustment for or stratification by maternal or parental BMI (3,10,11,31–39). Maternal pregavid obesity has been found to be a significant effect modifier in the association between breastfeeding and child overweight (33). Longer duration of breastfeeding was associated with lower prevalence of offspring overweight across all levels of maternal body size, but risk of overweight remained higher among children of obese women within each category of infant feeding. Specifically, children of obese mothers who did not breastfeed had the highest prevalence of overweight at 2–14 years of age (31.5%) compared with the children of normal-weight women who breastfed for 4 months or longer (6.0%) (33). Breastfeeding appears to confer protection against overweight for children of obese mothers.

Limitations of studies on breastfeeding and growth in children

There is a strong association between prolonged exclusive breastfeeding and lower risk of overweight in childhood and adolescence for the general population. Residual confounding by parental attributes and/or family environment is a potential limitation, because breastfeeding is a behavior that is self-selected and women are not randomized to breastfeeding or formula feeding. Sources of bias (41) include *1*) confounding by higher socioeconomic status of women in developed countries who choose to breastfeed and who are less likely to overfeed their infants, independent of the feeding method; *2*) reverse causality that "creates a bias in the opposite direction: slow-growing infants" may be deliberately supplemented or weaned to reverse this poor growth trend; and *3*) selection bias may result because "fast-growing infants" have greater hunger demands that leads to supplementation to reduce crying, and only infants whose growth demands are met by their mother's milk supply continue to breastfeed. Future studies should measure behavioral and feeding attributes of infants to quantify and estimate their impact on the risk estimates and whether biases exist.

One method to address these potential biases used a cluster-randomized design of breastfeeding support in the Republic of Belarus (41). Infants who received prolonged exclusive breastfeeding showed patterns of growth characterized by higher weight and length growth (*z* scores) through 3 months of age, with slower growth thereafter to 12 months of age compared with infants weaned at earlier ages. It is possible that breastfeeding may be a marker for more healthful behaviors in families rather than exerting a true biological effect. However, the robustness of the protective association in the general population, breastfeeding's effects on infant growth patterns, and emerging evidence of physiological differences in metabolism support a causal relationship.

EFFECTS OF BREASTFEEDING AND MATERNAL DIABETES DURING PREGNANCY ON THE OFFSPRING

— Maternal diabetes during pregnancy affects fetal growth and development through the altered intrauterine milieu. Relatively few studies have examined breastfeeding and subsequent obesity or diabetes in the offspring of women with GDM. Of seven studies, four included mixed samples of mothers with diabetes during pregnancy, women with pregestational diabetes, or women with GDM; two examined the offspring of Pima Indians and maternal diabetes status during pregnancy; and one

examined offspring of mothers with previous GDM only.

Breastfeeding and subsequent overweight and diabetes in offspring

Research on breastfeeding and subsequent diabetes in the offspring has been largely focused on women with type 1 diabetes. Less is known about breastfeeding and development of obesity and type 2 diabetes, specifically among the offspring of women with a history of GDM. Breastfeeding has been linked to lower rates of type 1 diabetes among genetically susceptible individuals (42). Early introduction of cow's milk or other foods are hypothesized to trigger autoimmune responses leading to type 1 diabetes, especially among children with high-risk HLA genotypes, but findings are inconclusive (43). Growth patterns among children of women with diabetes, including those with GDM, in general are slower after birth through the first 2 years of life, with rapid weight gain thereafter (44,45).

Differences in breast milk constituents between women with and without diabetes are hypothesized to affect infant growth and development of overweight. Whether breast milk from mothers with diabetes differentially influences early infant growth compared with banked donor breast milk has been evaluated in a nonrandomized longitudinal study of German children born to mothers with diabetes during pregnancy. The cohort included 83 women with type 1 diabetes and 29 women with GDM (46,47). The highest tertile of breast milk intake from mothers with diabetes during the first week of life was associated with twice the risk of overweight, defined as relative body weight above 110% at 2 years of age, compared with the lowest tertile (OR 1.91, 95% CI 1.10–3.30) (46). The association was strengthened after adjusting for age, sex, type of maternal diabetes, and maternal BMI (OR 2.51, 95% CI 1.32–5.04), and a stratified analysis of GDM women showed a similar trend. Furthermore, an inverse association with overweight risk was found for the highest versus lowest tertile of banked donor breast milk intake. A subsequent analysis of the same cohort examined the association between later breastfeeding and total duration of breastfeeding and risk of overweight at age 2 years in the offspring. These factors were strongly associated with child overweight in minimally adjusted models but exhibited no independent relationship once early neonatal breast milk from diabetic mothers was included in the model (47). Findings for impaired glucose tolerance during early or later neonatal periods were inconsistent. Limitations of the study include the following: lack of randomization to source of breast milk, no data on prenatal and postnatal maternal blood glucose control, no description of the specific indications for donor breast milk supplementation (e.g., poor infant feeding, neonatal hypoglycemia, and weight loss), and no adjustment for total volume of milk intake from all sources, which in 23 infants included artificial formula. Total volume of milk ingested tended to be higher among infants of mothers with GDM. Higher intake of breast milk from mothers with diabetes may merely be a marker for higher energy intake, leading to rapid growth that is driven by intrauterine "metabolic programming" rather than postnatal exposures.

In the Nurses' Health Study, risk of overweight (based on self-reported weight and height) at age 9–14 years among offspring of mothers who had diabetes during pregnancy (419 with GDM and 56 with pregestational diabetes) was inversely associated with having been breastfed during the first 6 months of life. This association was similar to that among offspring of normal-weight women (n = 8,617) and overweight women (n = 6,190) without diabetes during pregnancy (48). Another study of 324 offspring of mothers with GDM from Berlin, Germany, found that exclusive breastfeeding for >3 months was associated with a lower risk of overweight (>90th percentile) at ages 2–8 years (OR 0.55, 95% CI 0.33–0.91), but lower risk of overweight was limited to offspring of obese GDM mothers (49).

The first study to examine the relationship between breastfeeding and development of type 2 diabetes in the offspring was conducted in the Pima Indians, a population with a high prevalence of type 2 diabetes (7). Exclusive breastfeeding compared with exclusive bottle-feeding during infancy was associated with a lower prevalence of type 2 diabetes (OR 0.41, 95% CI 0.18–0.93) among individuals between the ages of 10 and 39 years adjusted for age, sex, parental diabetes, and birth weight (7). However, this study did not examine whether maternal diabetes during pregnancy altered the observed association with breastfeeding.

The only prospective study, to our knowledge, that examined breastfeeding and the risk of type 2 diabetes in the offspring of women with GDM involved this same cohort of Pima Indians. Women were tested with a 75-g oral glucose tolerance test during their pregnancies and were classified as having diabetes during pregnancy according to World Health Organization criteria. Follow-up of the women and their children starting at 5 years of age was conducted through a biennial standardized examination and oral glucose tolerance tests. Among offspring 10–39 years of age whose mothers did not have diabetes during pregnancy (n = 551), the adjusted prevalence of type 2 diabetes was 6.9% for those exclusively breastfed for at least 2 months and 11.9% for those not breastfed (OR 0.56, 95% CI 0.41–0.76) (50). Among 21 offspring whose mothers had diabetes during pregnancy, the prevalence of type 2 diabetes was lower for those exclusively breastfed versus those not breastfed (30.1 vs. 43.5%), but statistical significance was not reached (50). The risk estimates were adjusted for age, sex, birth weight, birth date, and the presence of diabetes in either parent. However, other potential confounders including sibship status and severity of diabetes during pregnancy were not taken into account.

A case-control study examined breastfeeding and risk of type 2 diabetes in the offspring in 46 children below 18 years of age with type 2 diabetes and 92 age- and sex-matched control subjects from a clinic serving Native Canadians. Their mothers had preexisting type 1 diabetes, GDM, or no diabetes during pregnancy. The risk of type 2 diabetes was lower among offspring who were breastfed longer than 12 months versus none (OR 0.24, 95% CI 0.13–0.84) adjusted for type of maternal diabetes during pregnancy (51). Only 22 of 138 mothers had GDM during pregnancy. Limitations of the study were that case and control subjects were not matched by actual birth year, the association was absent at shorter duration of breastfeeding, and there was no adjustment for parental socioeconomic status and area of residence.

A limitation of all studies is that risk estimates were not adjusted for maternal blood glucose control during pregnancy. To date, evidence that breastfeeding protects the offspring of women with GDM from developing overweight and type 2 diabetes is inconclusive.

Lactogenesis in women with previous GDM

Lactation may be more difficult for women with GDM because both maternal diabetes and obesity can delay the onset of lactogenesis (52,53). Furthermore, medical management of their newborns that involves provision of supplemental milk feedings may interfere with maternal milk production. In obese women, lactogenesis may be impaired because of lower physiological levels of prolactin in response to suckling (52). Delayed milk production may lead to lower rates of breastfeeding and shorter duration among obese women (53). A small sample of women with GDM were observed to have no marked delays based on similar concentration of lactose in the colostrum of GDM women compared with control women at 40–50 h postpartum (54). However, GDM women had more difficulty expressing colostrum from their breasts during the first 2 days of lactation.

Biological plausibility for breastfeeding and lower risk of overweight and diabetes

Postnatal growth patterns have been linked to future risk of overweight, but whether breastfeeding may affect early weight gain is unclear. The average daily milk volume consumed by an infant increases from 50 ml on day 1 to 500 ml by day 5 of life (55). Behavioral mechanisms include infant self-regulation of breast milk intake. Macronutrient composition (i.e., protein, fat, lactose content) of breast milk may influence hormonal responses that influence metabolic programming of body fatness and rates of growth. Levels of insulin, leptin, and ghrelin that regulate energy homeostasis in early neonatal life may be affected by the mode of infant feeding.

Breastfeeding and early neonatal growth

Breastfeeding may influence neonatal fat deposition that affects adiposity in childhood and adolescence that later tracks into adulthood. Animal studies demonstrate that overfeeding during infancy leads to higher adiposity during adolescence (56). In humans, a greater decline in weight for length *z* score between 3 and 12 months was found for breastfed compared with formula-fed infants (57,58). Both groups exhibited increased fatness in the first 6 months; but thereafter fatness decreased in both groups and more in the breastfed group. Mean weight-for-length was greater among formula-fed infants from 7–24 months and percent body fat was higher from 5–24 months. Lower energy intake among breastfed infants explained the difference between groups. Six other studies in North America and Europe showed similar findings, that is, infants who were breastfed for 12 months or longer tended to be leaner by 12–18 months of age (59). Others have reported slower growth during infancy for those breastfed compared with formula fed (60,61). Also, formula and other milk feedings compared with breast milk had "growth-accelerating effects on weight and length gain throughout infancy" as compared with breast milk (61). The dose-response gradient for this association was strongest at 3–6 months of age (61).

The early postnatal period has emerged as an important predictor of overweight in childhood (62–64) and adult life (65). In the U.S. Perinatal Collaborative Study of 19,937 infants born between 1959 and 1965, rapid weight gain during the first 4 months of life was associated with higher risk of overweight at age 7 years (63). The adjusted odds ratio for being overweight at age 7 years for every 100 g/month gained was 1.38 (95% CI 1.32–1.44). This association was attenuated (OR 1.17, 95% CI 1.11–1.24) but remained significant after adjustment for the weight attained at age 1 year. A limitation is that no data on method of infant feeding were available for this cohort, except initial type. In 653 healthy infants born in the region of Iowa City from 1965 to 1978 who were exclusively formula fed (65), rapid weight gain during the first week of life (>100 g/day) was associated with greater risk of becoming overweight as an adult, with a 28% increase in risk per 100 g gained (OR for each 100-g increase 1.28, 95% CI 1.08–1.52), as was weight gain during the first 112 days of life (OR 1.04, 95% CI 1.01–1.08). The influence of breastfeeding on growth rates during early neonatal life may be important to postnatal programming of adiposity.

Postulated mechanisms: constituents of breast milk and metabolic programming

Breastfeeding may exert protective biologic effects through behavioral and hormonal mechanisms that influence metabolic programming. Breast milk contains bioactive substances that may influence regulation of energy balance and fat deposition and has less protein relative to formula milk. Higher protein levels in early life have been linked to higher BMI later in life in some (66,67) but not all (68) studies. Higher insulin levels have also been reported in formula-fed compared with breastfed babies (69). The hormones leptin and ghrelin are involved in regulating food intake, energy homeostasis, and body weight. Leptin levels have been reported to be higher for breastfed than formula-fed infants in one (70) but not another (71) study. The circulating leptin levels were not only related to adipose tissue production, but may be contributed from human milk (70). Because ghrelin stimulates insulin secretion and body fat accretion in animals (72), higher ghrelin levels in formula-fed than breastfed infants (73) may influence early weight gain (74). Regulation of energy homeostasis in infancy via hormone levels in human milk and metabolic responses may be especially important for metabolic programming of infants of women with diabetes or previous GDM.

LACTATION AND SUBSEQUENT OBESITY AND DIABETES IN WOMEN

Lactation after pregnancy may have lasting effects on risk factors that influence future chronic disease risk for women. Evidence is conflicting about whether lactation promotes greater postpartum weight loss (75–85). Prospective studies in which maternal weights (not self-reported) were measured before or during early pregnancy have reported lower postpartum weight retention, more rapid return to pregravid weight, or greater weight loss within 1 year among lactating women (79,82,83,85–88). Prolonged breastfeeding (>6 months) compared with formula feeding was associated with a 2 kg greater maternal weight loss by 1 year postpartum (79,84), as well as a smaller waist girth after weaning (89). Total body fat mass loss at 1 year postpartum measured using dual X-ray absorptiometry was 2 kg greater for lactating women, but did not reach statistical significance possibly because of the small sample size (90). Longer duration of breastfeeding has also been associated with lower maternal weight gain 10–15 years later (91,92). Lactation may also influence long-term regulation of body weight as well as regional fat distribution in women.

Lactation: immediate and post-weaning effects on maternal metabolic parameters

Maternal postpartum glucose tolerance is enhanced in lactating women with recent GDM. Yet, it is uncertain whether lactation reduces risk of type 2 diabetes in women with previous GDM. Lactation markedly alters maternal fuel metabolism and increases energy expenditure by 15–25% (93,94). The 400–500 kcal/day required for milk production during the first 6 months by exclusively breastfeeding women is derived from maternal dietary intake, with an additional 170 kcal/day mobilized from fat stores, and/or decreased physical activity (55,94,95). About 50 g/day glucose is diverted for lactogenesis (the process of milk synthesis and secretion) via non–insulin-mediated pathways of uptake by the mammary gland (94). Thus, lactating women exhibit lower blood glucose and insulin concentrations along with higher rates of glucose production and lipolysis compared with nonlactating women (96).

In women with recent GDM, results of a frequently sampled intravenous glucose tolerance test showed that lactating ($n = 14$) versus nonlactating ($n = 12$) women had greater β-cell compensation for insulin resistance (97). Basal and glucose-stimulated β-cell secretory activity in response to a standardized glucose load was lower for lactating women than for nonlactating women (98). Greater non–insulin-mediated use of glucose for milk production may theoretically reduce the load on the β-cells and thereby delay or prevent the progression to type 2 diabetes. Whether prolonged exclusive breastfeeding by women with GDM has post-weaning effects on glucose tolerance and insulin sensitivity has not been examined.

Few studies have examined breastfeeding and postpartum glucose tolerance in women with previous GDM. Of 28 studies cited in a published review (99) and four subsequent studies (100–103) evaluating predictors of type 2 diabetes after GDM, only four specifically examined lactation (104–107). The definition of lactation in these studies was limited to "any" versus "none" at a single point in time (104–107), and few other postpartum behaviors were examined. Lactation has immediate beneficial effects on glucose tolerance, although evidence for lasting effects is more limited and inconclusive (104–107). In a cross-sectional study of Latinas with previous GDM attending family planning clinics, lactating women had a lower total area under the glucose tolerance curve and lower fasting serum glucose after controlling for BMI, maternal age, and insulin use during pregnancy (104). In this study, prevalence of type 2 diabetes for lactating women at 4–12 weeks postpartum was half that of nonlactating women (104). Other studies in the same clinic population report inconsistent findings. In 122 Latinas with normal fasting glucose and no insulin use during GDM pregnancy, those diagnosed with diabetes within 6 months postpartum were less likely to have breastfed (42%) than those with normal glucose tolerance (71%) (106). The same investigators found that lactation status (yes versus no) at 11–26 months postpartum did not influence diagnosis of type 2 diabetes in 91 Latinas with recent GDM (107). Lastly, a retrospective study of Latinas attending family planning clinics and tested via an oral glucose tolerance test at variable intervals found no association between lactation status at 4–16 weeks postpartum (yes versus no) and subsequent development of type 2 diabetes within 5 years (105).

Two studies examined the cumulative effects of lactation on future glucose tolerance among women in the general population. In a sample of 67 Brazilian women, increasing duration of lactation (weighted score) was inversely associated with the area under the insulin curve at 12–18 months postpartum independent of body adiposity (108). The Nurses' Health Study reported that increasing duration of lactation was associated with reduced risk of type 2 diabetes, with each additional year decreasing the risk by 15% among women in general. These effects were independent of current BMI and other risk factors, and risk reductions were stronger with exclusive breastfeeding (2). The retrospective analysis stratified by GDM status showed no association between lactation and risk of type 2 diabetes (2). These findings are based on over 150,000 nurses with several years of follow-up, but limitations include the retrospective assessment of lactation, lack of standardized time intervals for screening of type 2 diabetes, classification of diabetes and GDM status by self-report, and differences in rates of GDM screening by age.

Studies have generally used cross-sectional measures of lactation (current status at screening, ever versus never) and variable timing for assessment of glucose tolerance. They also lack data on maternal postpartum behaviors (dietary intake, physical activity). Whether breastfeeding delays or prevents the onset of type 2 diabetes in women with a history of GDM remains unknown, and prospective population-based studies are needed.

SUMMARY AND FUTURE RESEARCH DIRECTIONS

— Since 1986, the American Diabetes Association has recommended that women with GDM should be encouraged to breastfeed (109,110). Recommendations from the Fourth International Workshop-Conference on Gestational Diabetes Mellitus encouraged women to breastfeed, although data demonstrating efficacy were lacking (111). In the general population, breastfeeding is associated with a reduced risk of the offspring being overweight later in life by 20–50% across the age spectrum, from preschool children to adults. There is a dose-response gradient with increasing duration of breastfeeding and lowest risk with prolonged exclusive breastfeeding. This association may vary by maternal attributes such as pregravid obesity, smoking, diabetes during pregnancy, and race/ethnicity. Because randomization to breastfeeding versus formula is not desirable or ethical, the causal link is not definitive.

Among the offspring of women with GDM, evidence is inconclusive as to whether breastfeeding reduces their risk of overweight, obesity, and type 2 diabetes. Findings in Pima Indians suggest that lower rates of type 2 diabetes may occur in the offspring of both women with and without diabetes during pregnancy who were breastfed. Whether breastfeeding reduces risk of overweight in the offspring of GDM women is uncertain. Evidence that early neonatal intake of breast milk from women with diabetes during pregnancy adversely affects child growth requires confirmation as well as control for intrauterine influences on postnatal growth.

In women with a history of GDM, lactation has immediate favorable effects on glucose tolerance, but some data show that there are lasting post-weaning effects on maternal metabolic profiles (112). Maternal obesity, central adiposity, and weight gain subsequent to GDM pregnancy are strong predictors of type 2 diabetes in women several years later. Few data are available on the effects of lactation on these risk factors for type 2 diabetes among women with GDM and,

specifically, the effects of prolonged exclusive breastfeeding.

Prospective studies of women with GDM and their offspring are needed to evaluate whether breastfeeding *1*) leads to metabolic "programming" in early infancy after accounting for intrauterine exposures, *2*) prevents overweight and diabetes later in life among the offspring, *3*) reduces postpartum weight retention and/or central adiposity in women, and *4*) preserves maternal glucose tolerance to delay or prevent type 2 diabetes among women with previous GDM. More research is also needed to evaluate the influence of breast milk constituents as they relate to early infant growth patterns and future development of obesity and type 2 diabetes in the offspring.

Acknowledgments— This work was supported by Career Development Award Grant 2 K01 DK059944 from the National Institute of Diabetes, Digestive, and Kidney Diseases (NIDDK) and a Research Award from the American Diabetes Association.

Comments from Kathryn G. Dewey, PhD, Professor, University of California, Davis, were very helpful in preparing this manuscript.

References

1. Collaborative Group on Hormonal Factors in Breast Cancer: Breast cancer and breastfeeding: collaborative reanalysis of individual data from 47 epidemiological studies in 30 countries, including 50302 women with breast cancer and 96973 women without the disease. *Lancet* 360: 187–195, 2002
2. Stuebe AM, Rich-Edwards JW, Willett WC, Manson JE, Michels KB: Duration of lactation and incidence of type 2 diabetes. *JAMA* 294:2601–2610, 2005
3. Grummer-Strawn LM, Mei Z: Does breastfeeding protect against pediatric overweight? Analysis of longitudinal data from the Centers for Disease Control and Prevention Pediatric Nutrition Surveillance System. *Pediatrics* 113:e81–e86, 2004
4. Arenz S, von Kries R: Protective effect of breastfeeding against obesity in childhood: can a meta-analysis of observational studies help to validate the hypothesis? *Adv Exp Med Biol* 569:40–48, 2005
5. Ravelli AC, van der Meulen JH, Osmond C, Barker DJ, Bleker OP: Infant feeding and adult glucose tolerance, lipid profile, blood pressure, and obesity. *Arch Dis Child* 82:248–252, 2000
6. Rich-Edwards JW, Stampfer MJ, Manson JE, Rosner B, Hu FB, Michels KB, Willett WC: Breastfeeding during infancy and the risk of cardiovascular disease in adulthood. *Epidemiology* 15:550–556, 2004
7. Pettitt DJ, Forman MR, Hanson RL, Knowler WC, Bennett PH: Breastfeeding and incidence of non-insulin-dependent diabetes mellitus in Pima Indians. *Lancet* 350:166–168, 1997
8. Lucas A, Fewtrell MS, Cole TJ: Fetal origins of adult disease: the hypothesis revisited. *BMJ* 319:245–249, 1999
9. Barker DJ, Eriksson JG, Forsen T, Osmond C: Fetal origins of adult disease: strength of effects and biological basis. *Int J Epidemiol* 31:1235–1239, 2002
10. Dewey KG: Is breastfeeding protective against child obesity? *J Hum Lact* 19:9–18, 2003
11. Arenz S, Ruckerl R, Koletzko B, von Kries R: Breast-feeding and childhood obesity: a systematic review. *Int J Obes Relat Metab Disord* 28:1247–1256, 2004
12. Owen CG, Martin RM, Whincup PH, Smith GD, Cook DG: Effect of infant feeding on the risk of obesity across the life course: a quantitative review of published evidence. *Pediatrics* 115:1367–1377, 2005
13. Harder T, Bergmann R, Kallischnigg G, Plagemann A: Duration of breastfeeding and risk of overweight: a meta-analysis. *Am J Epidemiol* 162:397–403, 2005
14. Whitaker RC, Dietz WH: Role of the prenatal environment in the development of obesity. *J Pediatr* 132:768–776, 1998
15. Pettitt DJ, Nelson RG, Saad MF, Bennett PH, Knowler WC: Diabetes and obesity in the offspring of Pima Indian women with diabetes during pregnancy. *Diabetes Care* 16:310–314, 1993
16. Plagemann A, Harder T, Kohlhoff R, Rohde W, Dorner G: Overweight and obesity in infants of mothers with long-term insulin-dependent diabetes or gestational diabetes. *Int J Obes Relat Metab Disord* 21:451–456, 1997
17. Gillman MW, Rifas-Shiman S, Berkey CS, Field AE, Colditz GA: Maternal gestational diabetes, birth weight, and adolescent obesity. *Pediatrics* 111:e221–e226, 2003
18. Schaefer-Graf UM, Pawliczak J, Passow D, Hartmann R, Rossi R, Buhrer C, Harder T, Plagemann A, Vetter K, Kordonouri O: Birth weight and parental BMI predict overweight in children from mothers with gestational diabetes. *Diabetes Care* 28:1745–1750, 2005
19. Whitaker RC, Pepe MS, Seidel KD, Wright JA, Knopp RH: Gestational diabetes and the risk of offspring obesity. *Pediatrics* 101:E9, 1998
20. Gartner LM, Morton J, Lawrence RA, Naylor AJ, O'Hare D, Schanler RJ, Eidelman AI: Breastfeeding and the use of human milk. *Pediatrics* 115:496–506, 2005
21. Institute of Medicine: *Nutrition During Lactation.* Washington, DC, National Academy Press, 1991
22. Ryan AS, Wenjun Z, Acosta A: Breastfeeding continues to increase into the new millennium. *Pediatrics* 110:1103–1109, 2002
23. Li R, Darling N, Maurice E, Barker L, Grummer-Strawn LM: Breastfeeding rates in the United States by characteristics of the child, mother, or family: the 2002 National Immunization Survey. *Pediatrics* 115:e31–e37, 2005
24. Troiano RP, Flegal KM: Overweight children and adolescents: description, epidemiology, and demographics. *Pediatrics* 101:497–504, 1998
25. Hedley AA, Ogden CL, Johnson CL, Carroll MD, Curtin LR, Flegal KM: Prevalence of overweight and obesity among US children, adolescents, and adults, 1999–2002. *JAMA* 291:2847–2850, 2004
26. Serdula MK, Ivery D, Coates RJ, Freedman DS, Williamson DF, Byers T: Do obese children become obese adults? A review of the literature. *Prev Med* 22: 167–177, 1993
27. Whitaker RC, Wright JA, Pepe MS, Seidel KD, Dietz WH: Predicting obesity in young adulthood from childhood and parental obesity. *N Engl J Med* 337:869–873, 1997
28. Monteiro PO, Victora CG: Rapid growth in infancy and childhood and obesity in later life: a systematic review. *Obes Rev* 6:143–154, 2005
29. Forsen T, Eriksson J, Tuomilehto J, Reunanen A, Osmond C, Barker D: The fetal and childhood growth of persons who develop type 2 diabetes. *Ann Intern Med* 133:176–182, 2000
30. Dietz WH: Health consequences of obesity in youth: childhood predictors of adult disease. *Pediatrics* 101:518–525, 1998
31. Bogen DL, Hanusa BH, Whitaker RC: The effect of breast-feeding with and without formula use on the risk of obesity at 4 years of age. *Obes Res* 12:1527–1535, 2004
32. Nelson MC, Gordon-Larsen P, Adair LS: Are adolescents who were breast-fed less likely to be overweight? Analyses of sibling pairs to reduce confounding. *Epidemiology* 16:247–253, 2005
33. Li C, Kaur H, Choi WS, Huang TT, Lee RE, Ahluwalia JS: Additive interactions of maternal prepregnancy BMI and breast-feeding on childhood overweight. *Obes Res* 13:362–371, 2005
34. Kvaavik E, Tell GS, Klepp KI: Surveys of Norwegian youth indicated that breast feeding reduced subsequent risk of obesity. *J Clin Epidemiol* 58:849–855, 2005
35. Reilly JJ, Armstrong J, Dorosty AR, Emmett PM, Ness A, Rogers I, Steer C, Sherriff A: Early life risk factors for obesity in childhood: cohort study. *BMJ* 330:1357,

2005
36. Burke V, Beilin LJ, Simmer K, Oddy WH, Blake KV, Doherty D, Kendall GE, Newnham JP, Landau LI, Stanley FJ: Breastfeeding and overweight: longitudinal analysis in an Australian birth cohort. *J Pediatr* 147:56–61, 2005
37. Victora CG, Barros F, Lima RC, Horta BL, Wells J: Anthropometry and body composition of 18 year old men according to duration of breast feeding: birth cohort study from Brazil. *BMJ* 327:901, 2003
38. Bergmann KE, Bergmann RL, von Kries R, Bohm O, Richter R, Dudenhausen JW, Wahn U: Early determinants of childhood overweight and adiposity in a birth cohort study: role of breast-feeding. *Int J Obes Relat Metab Disord* 27:162–172, 2003
39. Li L, Parsons TJ, Power C: Breast feeding and obesity in childhood: cross sectional study. *BMJ* 327:904–905, 2003
40. Whitaker RC: Predicting preschooler obesity at birth: the role of maternal obesity in early pregnancy. *Pediatrics* 114: e29–e36, 2004
41. Kramer MS, Guo T, Platt RW, Shapiro S, Collet JP, Chalmers B, Hodnett E, Sevkovskaya Z, Dzikovich I, Vanilovich I: Breastfeeding and infant growth: biology or bias? *Pediatrics* 110:343–347, 2002
42. Virtanen SM, Rasanen L, Ylonen K, Aro A, Clayton D, Langholz B, Pitkaniemi J, Savilahti E, Lounamaa R, Tuomilehto J: Early introduction of dairy products associated with increased risk of IDDM in Finnish children: the Childhood in Diabetes in Finland Study Group. *Diabetes* 42:1786–1790, 1993
43. Virtanen SM, Knip M: Nutritional risk predictors of beta cell autoimmunity and type 1 diabetes at a young age. *Am J Clin Nutr* 78:1053–1067, 2003
44. Touger L, Looker HC, Krakoff J, Lindsay RS, Cook V, Knowler WC: Early growth in offspring of diabetic mothers. *Diabetes Care* 28:585–589, 2005
45. Silverman BL, Rizzo TA, Cho NH, Metzger BE: Long-term effects of the intrauterine environment: the Northwestern University Diabetes in Pregnancy Center. *Diabetes Care* 21 (Suppl. 2): B142–B149, 1998
46. Plagemann A, Harder T, Franke K, Kohlhoff R: Long-term impact of neonatal breast-feeding on body weight and glucose tolerance in children of diabetic mothers. *Diabetes Care* 25:16–22, 2002
47. Rodekamp E, Harder T, Kohlhoff R, Franke K, Dudenhausen JW, Plagemann A: Long-term impact of breast-feeding on body weight and glucose tolerance in children of diabetic mothers: role of the late neonatal period and early infancy. *Diabetes Care* 28:1457–1462, 2005
48. Mayer-Davis EJ, Rifas-Shiman SL, Hu F, Colditz G, Gilman M: Breast feeding and risk for childhood obesity: does diabetes or obesity status matter? *Pediatr Res* 58: 1027–1028, 2005
49. Schaefer-Graf UM, Hartmann R, Pawliczak J, Passow D, Abou-Dakn M, Vetter K, Kordonouri O: Association of breastfeeding and early childhood overweight in children from mothers with gestational diabetes mellitus. *Diabetes Care* 29:1105–1107, 2006
50. Pettitt DJ, Knowler WC: Long-term effects of the intrauterine environment, birth weight, and breast-feeding in Pima Indians. *Diabetes Care* 21 (Suppl. 2): B138–B141, 1998
51. Young TK, Martens PJ, Taback SP, Sellers EA, Dean HJ, Cheang M, Flett B: Type 2 diabetes mellitus in children: prenatal and early infancy risk factors among native Canadians. *Arch Pediatr Adolesc Med* 156:651–655, 2002
52. Rasmussen KM, Kjolhede CL: Prepregnant overweight and obesity diminish the prolactin response to suckling in the first week postpartum. *Pediatrics* 113: e465–e471, 2004
53. Donath SM, Amir LH: Does maternal obesity adversely affect breastfeeding initiation and duration? *Breastfeed Rev* 8:29–33, 2000
54. Hartmann P, Cregan M: Lactogenesis and the effects of insulin-dependent diabetes mellitus and prematurity. *J Nutr* 131:3016S–3020S, 2001
55. Picciano MF: Pregnancy and lactation: physiological adjustments, nutritional requirements and the role of dietary supplements. *J Nutr* 133:1997S–2002S, 2003
56. Lewis DS, Bertrand HA, McMahan CA, McGill HC Jr, Carey KD, Masoro EJ: Preweaning food intake influences the adiposity of young adult baboons. *J Clin Invest* 78:899–905, 1986
57. Dewey KG, Heinig MJ, Nommsen LA, Peerson JM, Lonnerdal B: Breast-fed infants are leaner than formula-fed infants at 1 y of age: the DARLING study. *Am J Clin Nutr* 57:140–145, 1993
58. Dewey KG, Heinig MJ, Nommsen LA, Peerson JM, Lonnerdal B: Growth of breast-fed and formula-fed infants from 0 to 18 months: the DARLING Study. *Pediatrics* 89:1035–1041, 1992
59. Dewey KG, Peerson JM, Brown KH, Krebs NF, Michaelsen KF, Persson LA, Salmenpera L, Whitehead RG, Yeung DL: Growth of breast-fed infants deviates from current reference data: a pooled analysis of US, Canadian, and European data sets: World Health Organization Working Group on Infant Growth. *Pediatrics* 96:495–503, 1995
60. Ong KK, Preece MA, Emmett PM, Ahmed ML, Dunger DB: Size at birth and early childhood growth in relation to maternal smoking, parity and infant breast-feeding: longitudinal birth cohort study and analysis. *Pediatr Res* 52:863–867, 2002
61. Kramer MS, Guo T, Platt RW, Vanilovich I, Sevkovskaya Z, Dzikovich I, Michaelsen KF, Dewey K: Feeding effects on growth during infancy. *J Pediatr* 145:600–605, 2004
62. Ong KK, Ahmed ML, Emmett PM, Preece MA, Dunger DB: Association between postnatal catch-up growth and obesity in childhood: prospective cohort study. *BMJ* 320:967–971, 2000
63. Stettler N, Zemel BS, Kumanyika S, Stallings VA: Infant weight gain and childhood overweight status in a multicenter, cohort study. *Pediatrics* 109:194–199, 2002
64. Cameron N, Pettifor J, de Wet T, Norris S: The relationship of rapid weight gain in infancy to obesity and skeletal maturity in childhood. *Obes Res* 11:457–460, 2003
65. Stettler N, Stallings VA, Troxel AB, Zhao J, Schinnar R, Nelson SE, Ziegler EE, Strom BL: Weight gain in the first week of life and overweight in adulthood: a cohort study of European American subjects fed infant formula. *Circulation* 111: 1897–1903, 2005
66. Rolland-Cachera MF, Deheeger M, Akrout M, Bellisle F: Influence of macronutrients on adiposity development: a follow up study of nutrition and growth from 10 months to 8 years of age. *Int J Obes Relat Metab Disord* 19:573–578, 1995
67. Koletzko B, Broekaert I, Demmelmair H, Franke J, Hannibal I, Oberle D, Schiess S, Baumann BT, Verwied-Jorky S: Protein intake in the first year of life: a risk factor for later obesity? The E.U. childhood obesity project. *Adv Exp Med Biol* 569:69–79, 2005
68. Dorosty AR, Emmett PM, Cowin S, Reilly JJ: Factors associated with early adiposity rebound: ALSPAC Study Team. *Pediatrics* 105:1115–1118, 2000
69. Lucas A, Boyes S, Bloom SR, Aynsley-Green A: Metabolic and endocrine responses to a milk feed in six-day-old term infants: differences between breast and cow's milk formula feeding. *Acta Paediatr Scand* 70:195–200, 1981
70. Savino F, Nanni GE, Maccario S, Costamagna M, Oggero R, Silvestro L: Breast-fed infants have higher leptin values than formula-fed infants in the first four months of life. *J Pediatr Endocrinol Metab* 17:1527–1532, 2004
71. Lonnerdal B, Havel PJ: Serum leptin concentrations in infants: effects of diet, sex, and adiposity. *Am J Clin Nutr* 72: 484–489, 2000
72. Tschop M, Smiley DL, Heiman ML: Ghrelin induces adiposity in rodents. *Nature* 407:908–913, 2000
73. Savino F, Fissore MF, Grassino EC, Nanni GE, Oggero R, Silvestro L: Ghre-

lin, leptin and IGF-I levels in breast-fed and formula-fed infants in the first years of life. *Acta Paediatr* 94:531–537, 2005
74. Savino F, Liguori SA, Fissore MF, Oggero R, Silvestro L, Miniero R: Serum ghrelin concentration and weight gain in healthy term infants in the first year of life. *J Pediatr Gastroenterol Nutr* 41:653–659, 2005
75. Sichieri R, Field AE, Rich-Edwards J, Willett WC: Prospective assessment of exclusive breastfeeding in relation to weight change in women. *Int J Obes Relat Metab Disord* 27:815–820, 2003
76. Coitinho DC, Sichieri R, D'Aquino Benicio MH: Obesity and weight change related to parity and breast-feeding among parous women in Brazil. *Public Health Nutr* 4:865–870, 2001
77. Wosje KS, Kalkwarf HJ: Lactation, weaning, and calcium supplementation: effects on body composition in postpartum women. *Am J Clin Nutr* 80: 423–429, 2004
78. 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
79. Dewey KG, Heinig MJ, Nommsen LA: Maternal weight-loss patterns during prolonged lactation. *Am J Clin Nutr* 58: 162–166, 1993
80. Dewey KG: Impact of breastfeeding on maternal nutritional status. *Adv Exp Med Biol* 554:91–100, 2004
81. Heinig MJ, Dewey KG: Health effects of breastfeeding for mothers: a critical review. *Nutr Res Rev* 10:35–56, 1997
82. Olson CM, Strawderman MS, Hinton PS, Pearson TA: Gestational weight gain and postpartum behaviors associated with weight change from early pregnancy to 1 y postpartum. *Int J Obes Relat Metab Disord* 27:117–127, 2003
83. Ohlin A, Rossner S: Maternal body weight development after pregnancy. *Int J Obes* 14:159–173, 1990
84. Janney CA, Zhang D, Sowers M: Lactation and weight retention. *Am J Clin Nutr* 66:1116–1124, 1997
85. McKeown T, Record RG: The influence of reproduction on body weight in women. *J Endocrinol* 15:393–409, 1957
86. Olson CM, Strawderman MS: Modifiable behavioral factors in a biopsychosocial model predict inadequate and excessive gestational weight gain. *J Am Diet Assoc* 103:48–54, 2003
87. van Raaij JM, Schonk CM, Vermaat-Miedema SH, Peek ME, Hautvast JG: Energy cost of lactation, and energy balances of well-nourished Dutch lactating women: reappraisal of the extra energy requirements of lactation. *Am J Clin Nutr* 53:612–619, 1991
88. Sadurskis A, Kabir N, Wager J, Forsum E: Energy metabolism, body composition, and milk production in healthy Swedish women during lactation. *Am J Clin Nutr* 48:44–49, 1988
89. Gigante DP, Victora CG, Barros FC: Breast-feeding has a limited long-term effect on anthropometry and body composition of Brazilian mothers. *J Nutr* 131:78–84, 2001
90. Butte NF, Hopkinson JM: Body composition changes during lactation are highly variable among women. *J Nutr* 128:381S–385S, 1998
91. Rooney BL, Schauberger CW: Excess pregnancy weight gain and long-term obesity: one decade later. *Obstet Gynecol* 100:245–252, 2002
92. Linne Y, Dye L, Barkeling B, Rossner S: Weight development over time in parous women: the SPAWN study: 15 years follow-up. *Int J Obes Relat Metab Disord* 27:1516–1522, 2003
93. Dewey KG: Energy and protein requirements during lactation. *Annu Rev Nutr* 17:19–36, 1997
94. Butte NF, Hopkinson JM, Mehta N, Moon JK, Smith EO: Adjustments in energy expenditure and substrate utilization during late pregnancy and lactation. *Am J Clin Nutr* 69:299–307, 1999
95. Motil KJ, Montandon CM, Garza C: Basal and postprandial metabolic rates in lactating and nonlactating women. *Am J Clin Nutr* 52:610–615, 1990
96. Tigas S, Sunehag A, Haymond MW: Metabolic adaptation to feeding and fasting during lactation in humans. *J Clin Endocrinol Metab* 87:302–307, 2002
97. McManus RM, Cunningham I, Watson A, Harker L, Finegood DT: Beta-cell function and visceral fat in lactating women with a history of gestational diabetes. *Metabolism* 50:715–719, 2001
98. Hubinont CJ, Balasse H, Dufrane SP, Leclercq-Meyer V, Sugar J, Schwers J, Malaisse WJ: Changes in pancreatic B cell function during late pregnancy, early lactation and postlactation. *Gynecol Obstet Invest* 25:89–95, 1988
99. Kim C, Newton KM, Knopp RH: Gestational diabetes and the incidence of type 2 diabetes: a systematic review. *Diabetes Care* 25:1862–1868, 2002
100. Albareda M, Caballero A, Badell G, Piquer S, Ortiz A, De Leiva A, Corcoy R: Diabetes and abnormal glucose tolerance in women with previous gestational diabetes. *Diabetes Care* 26:1199–1205, 2003
101. Pallardo LF, Herranz L, Martin-Vaquero P, Garcia-Ingelmo T, Grande C, Janez M: Impaired fasting glucose and impaired glucose tolerance in women with prior gestational diabetes are associated with a different cardiovascular profile. *Diabetes Care* 26:2318–2322, 2003
102. Aberg AE, Jonsson EK, Eskilsson I, Landin-Olsson M, Frid AH: Predictive factors of developing diabetes mellitus in women with gestational diabetes. *Acta Obstet Gynecol Scand* 81:11–16, 2002
103. Dalfra MG, Lapolla A, Masin M, Giglia G, Dalla BB, Toniato R, Fedele D: Antepartum and early postpartum predictors of type 2 diabetes development in women with gestational diabetes mellitus. *Diabete Metab* 27:675–680, 2001
104. Kjos SL, Henry O, Lee RM, Buchanan TA, Mishell DR Jr: The effect of lactation on glucose and lipid metabolism in women with recent gestational diabetes. *Obstet Gynecol* 82:451–455, 1993
105. Kjos SL, Peters RK, Xiang A, Henry OA, Montoro M, Buchanan TA: Predicting future diabetes in Latino women with gestational diabetes: utility of early postpartum glucose tolerance testing. *Diabetes* 44:586–591, 1995
106. Buchanan TA, Xiang A, Kjos SL, Lee WP, Trigo E, Nader I, Bergner EA, Palmer JP, Peters RK: Gestational diabetes: antepartum characteristics that predict postpartum glucose intolerance and type 2 diabetes in Latino women. *Diabetes* 47: 1302–1310, 1998
107. Buchanan TA, Xiang AH, Kjos SL, Trigo E, Lee WP, Peters RK: Antepartum predictors of the development of type 2 diabetes in Latino women 11–26 months after pregnancies complicated by gestational diabetes. *Diabetes* 48:2430–2436, 1999
108. Diniz JM, Da Costa TH: Independent of body adiposity, breast-feeding has a protective effect on glucose metabolism in young adult women. *Br J Nutr* 92:905–912, 2004
109. American Diabetes Association: Position statement on gestational diabetes mellitus. *Diabetes Care* 9:430–431, 1986
110. American Diabetes Association: Gestational diabetes mellitus (Position Statement). *Diabetes Care* 27 (Suppl. 1):S88–S90, 2004
111. Metzger BE, Coustan DR: Summary and recommendations of the Fourth International Workshop-Conference on Gestational Diabetes Mellitus: The Organizing Committee. *Diabetes Care* 21 (Suppl. 2): B161–B167, 1998
112. Gunderson EP, Lewis CE, Wei GS, Whitmer RA, Quesenberry CP, Sidney S: Lactation and changes in maternal metabolic risk factors. *Obstet Gynecol* 109: 729–738, 2007