Carbohydrate Content in the GDM Diet: Two Views

View 1: Nutrition Therapy in Gestational Diabetes: The Case for Complex Carbohydrates

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IN BRIEF Restriction of dietary carbohydrate has been the cornerstone for treatment of gestational diabetes mellitus (GDM). However, there is evidence that a balanced liberalization of complex carbohydrate as part of an overall eating plan in GDM meets treatment goals and may mitigate maternal adipose tissue insulin resistance, both of which may promote optimal metabolic outcomes for mother and offspring.

Nutrition therapy is the most formative approach to treating gestational diabetes mellitus (GDM). In pregnancy, a prevailing maternal metabolic adaptation is the shift in glucose metabolism from insulin sensitivity to insulin resistance, exemplified by higher circulating lipids, heightened postprandial glucose, and increased β-cell demand/response (1,2). These intriguing exacerbations of human physiology are recognized to be additive to the prepregnancy phenotype (3), now largely characterized by overweight and obesity (4). When women cannot adapt to the glycemic demands of pregnancy, hyperglycemia and glucose intolerance manifest by the late second trimester, and this is recognized as GDM (5). There is hope that optimal nutrition therapy can offer a lower-cost treatment strategy for the rising number of women with GDM, which is anticipated to encompass 18% of all pregnancies after new diagnostic criteria are adopted (6,7). A treatment approach that circumvents expensive medication, reduces intensified fetal surveillance, and favorably affects both maternal and infant health is crucial.

The conventional approach to nutrition therapy in GDM has focused on carbohydrate restriction (8). Although effective based on clinical experience, this approach is perhaps the most challenging component to treatment adherence in GDM. Moreover, the paucity of evidence supporting carbohydrate restriction or any diet prescription in GDM has now been recognized. With carbohydrate restriction comes the potential for increased dietary fat intake, and mounting evidence supports a strong association between maternal lipids (i.e., triglycerides and free fatty acids [FFAs]) and excess fetal growth (9). Accordingly, in 2005, the American Diabetes Association withdrew nutrition therapy guidelines for GDM (10). To date, there is no consensus on the optimal diet for women with GDM, emphasizing the need for highly controlled randomized trials (10–12).

A more contemporary understanding of dietary complex carbohydrate has underscored a differential impact on postprandial glucose, wherein some polysaccharides and starches (primarily from whole grains, starchy vegetables, and legumes) tend to mitigate a sharp rise in postprandial glucose (13). This raises the possibility that nutrition therapy in GDM may safely include more complex, nutrient-dense carbohydrate than the conventional restrictive approach has

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DOI: 10.2337/diaspect.29.2.82

allowed. The purpose of this article is to review the background, evidence, and rationale for a balanced liberalization of complex carbohydrate within nutrition therapy regimens for women with GDM.

Potential of Nutrition Therapy to Break a Relentless Cycle

A balanced, effective macronutrient diet composition in GDM could improve maternal glycemia, but simultaneously could prevent worsening of maternal metabolic parameters that lead to excessive fetal growth. GDM has the potential to create a relentless cycle of obesity and diabetes prevalence. Up to 50% of mothers with GDM will develop type 2 diabetes within 10–20 years of their pregnancy (14–17). Moreover, the offspring of women with GDM are at risk for being large for gestational age (LGA) (18), having increased adiposity (19,20), and developing impaired glucose tolerance (21,22), metabolic syndrome (23), and type 2 diabetes (15,16,24–26). Strong positive associations between infant birth weight and later BMI support that larger newborns are more likely to become obese adults (18,27), and females born LGA (≥90th percentile) have a doubled risk for delivering an LGA infant themselves (28). Because the risk is attributed to in utero exposure to diabetes or GDM (26,29,30), women with GDM perpetuate a cycle of obesity and diabetes prevalence through generations when affected daughters become pregnant (31). Overweight and obesity currently affect up to 75% of young women in the United States (32), and, as GDM prevalence increases, the GDM intrauterine metabolic environment is expected to further fuel the risk of offspring obesity and glucose intolerance (33). Nutrition therapy holds great potential to effectively treat this growing population of mothers and offspring.

Stress, Anxiety, and Fear as Barriers to GDM Nutrition Therapy Treatment

A GDM diagnosis generates stress, anxiety, and fear, all of which may undermine any approach to nutrition therapy. Until the diagnosis at ~28 weeks' gestation, most women have experienced a "normal" pregnancy, during which the development of GDM has occurred asymptomatically (34). The diagnosis suddenly necessitates a high-risk pregnancy label, adherence to nutrition therapy, and heightened surveillance. Anxiety and depression in these women may stem from self-blame (34), feelings of loss of control (35,36), fear of macrosomia or infant complications (36,37), feelings of being misunderstood by their partner (38), and fear of future type 2 diabetes (34), all of which are magnified by the confining high-risk pregnancy label and controlled or restrictive nature of nutrition therapy (36–38).

Women with GDM have expressed feeling an intense moral obligation to the health of their unborn child, motivating them to endure intensified management (38). Although they are motivated to modify their lifestyle, adherence to nutrition therapy has been identified as the most arduous, confining component of treatment (34,36,37). Nutrition therapy has been described as intrusive (34) and an infringement on cultural/social roles, beliefs, and diet practices (35,36,39). Quick adaptation to a new diet composition late in pregnancy is challenging (34,40). Many women do not understand food properties (i.e., types of carbohydrates and types of fats), making food choices mentally taxing (40). In our clinic, women with GDM were so fearful of macrosomia that they followed extreme carbohydrate-restricted diets, opting to replace calories from carbohydrates with calories from fat. Although this practice resulted in controlled glycemia, mounting evidence supports a potential deleterious intrauterine programming effect of FFAs on aberrant fetal growth and long-term infant health outcomes (41,42).

Unintended Consequences of Carbohydrate Restriction in GDM?

Nutrition therapy is the first line of treatment for women with GDM. If effective, glycemia is controlled, and adequate weight gain and nutritional status are supported (12,43). Twenty years ago, it was reported based on clinical experience that a carbohydrate-restricted diet (40%) in GDM blunted postprandial glucose excursions (8). This observation fueled the focus on dietary carbohydrate and was corroborated when a strong association between maternal postprandial glycemia and infant size was reported (44,45). Although there is a rationale for carbohydrate restriction (i.e., glucose control), it also creates a context for unbalanced macronutrient intake. In obesogenic environments, a focus on carbohydrate restriction facilitates an increase in dietary fat due to the abundance and cost-effective availability of saturated fats and processed foods (46,47). A large increase in protein is unlikely because it is consumed consistently in humans (46). An unbalanced increase in protein (i.e., without appropriate micronutrient intake) within pregnancy diets has been linked to reduced birth weight (48).

A diet-induced worsening of maternal insulin resistance (49,50) could further increase nutrient delivery to the fetus and worsen fetal hyperinsulinemia (51). Emerging data in animal and nonhuman primate models support an intrauterine influence of dietary fat in promoting offspring adiposity, hepatic steatosis, and metabolic syndrome (42,52). In humans, maternal triglyceride and FFA levels may be stronger predictors of excess fetal fat accretion than maternal glucose (9,53), raising the question of whether glycemia should constitute the only focus for therapy in GDM (54).

TABLE 1. Comparison of Nutrition Therapy Recommendations for GDM From Professional Health Care Organizations*

Guidelines	Recommendations
ADA 5th International Workshop-Conference on GDM, 2005 (10)	Insufficient evidence; recommendations withdrawn
ADA Medical Nutrition Therapy Guidelines, 2013 (83)[a]	Inconclusive evidence; individualization needed
ACOG Guidelines, 2013 (5)	Carbohydrate 33–40% of total calories
The Endocrine Society Guidelines, 2013 (55)	Carbohydrate 35–45% of total calories
American Heart Association/American College of Cardiology (AHA/ACC) Guidelines, 2013 (57)[a,b]	Carbohydrate 55–59%, fat 26–27%, saturated fat 5–6%, and protein 15–18% of total calories

**For further comparison, recommendations from the ADA for diabetes outside of pregnancy and from the AHA/ACC for cardiometabolic health outside of pregnancy are included.*

[a]Recommendations for diabetes management outside of pregnancy.

[b]Lifestyle recommendations to reduce the risk of cardiovascular disease.

Consensus panels, recognizing the metabolic impact of dietary macronutrients beyond carbohydrate, have withheld specific diet recommendations because of insufficient evidence (10). Despite the lack of evidence, the American College of Obstetricians and Gynecologists (ACOG) (5) and the Endocrine Society (55) still refer to carbohydrate restriction (33–40% of total calories) as the approach to treatment. Mixed messages are conveyed to providers from consensus panels emphasizing glycemic and cardiometabolic health, within and outside of pregnancy (Table 1). Because women with GDM and their offspring are known to have heightened risk for type 2 diabetes and cardiovascular disease, overall glycemic and cardiovascular health are relevant considerations. For example, if a heart-healthy eating plan (56,57) can meet GDM management goals, it might also create an optimal intrauterine environment and a healthy long-term maternal postpartum nutritional pattern. Although limiting carbohydrate can control glycemia, the influence of a carbohydrate-restricted, higher-fat diet in obese women with prepregnancy insulin resistance may unintentionally promote intrauterine overnutrition.

Higher-Complex-Carbohydrate Diets in GDM: Challenging the Dogma

Restriction of dietary carbohydrate has been the cornerstone of diabetes treatment for >100 years. Before insulin, a diet prescription of ~8% carbohydrate and ~70% fat nearly eliminated glycosuria (58). Early 20th century pioneers in diabetes management established that a low-carbohydrate diet prescription required individualization but is generally ≤40% of total calories (58). As early management protocols for diabetes in pregnancy emerged to focus on "good" glycemic control to reduce maternal and fetal complications (59,60), nutrition therapy for GDM evolved to focus on control of maternal glucose. Data from later, nonrandomized trials supported carbohydrate restriction (61) by demonstrating blunted insulin secretion in response to a meal high in saturated fatty acids (62) and less need for insulin therapy with a carbohydrate intake <42% (63). However, carbohydrate restriction to <39% has been linked to the highest infant birth weights (64). Most studies of nutrition therapy in GDM are riddled with confounding insulin use, lack of compliance, heterogeneity in outcome reporting, and the absence of reported infant outcomes (i.e., birth weight and body composition) (11,12).

Grounded in the concern about increased fat intake, we asked a question to challenge the dogma emphasizing carbohydrate restriction in GDM. What if nutrition therapy in GDM focused on liberalization of complex carbohydrate instead of restriction of all carbohydrate? A salient finding across the few published randomized, controlled trials was that diets that were higher in complex carbohydrate and low–glycemic index foods (55–70% carbohydrate) were well tolerated 65–67). In fact, in GDM, diets higher in unrefined/complex carbohydrate have effectively blunted postprandial glycemia (65,68), reduced the need for insulin therapy (66), lowered fasting LDL cholesterol levels (65,69) and FFAs (65), and improved insulin sensitivity (70), A1C (69), and systolic blood pressure (69).

Thus, we developed a diet to challenge the low-carbohydrate diet for GDM (13). We have named this diet CHOICE (Choosing Healthy Options in Carbohydrate Energy), emphasizing an overall cardiometabolically healthy, nutrient-dense eating plan (57) that encourages choosing the right kinds of carbohydrate to control glycemia (unrefined/complex/nutrient-dense), instead of restricting total carbohydrate. Recently, we demonstrated in a controlled, randomized crossover study (all food provided, diet-controlled GDM), that, compared to a low-carbohydrate diet (40% carbohydrate/45% fat), the CHOICE diet (60% carbohydrate/25% fat) effectively controlled glycemia to

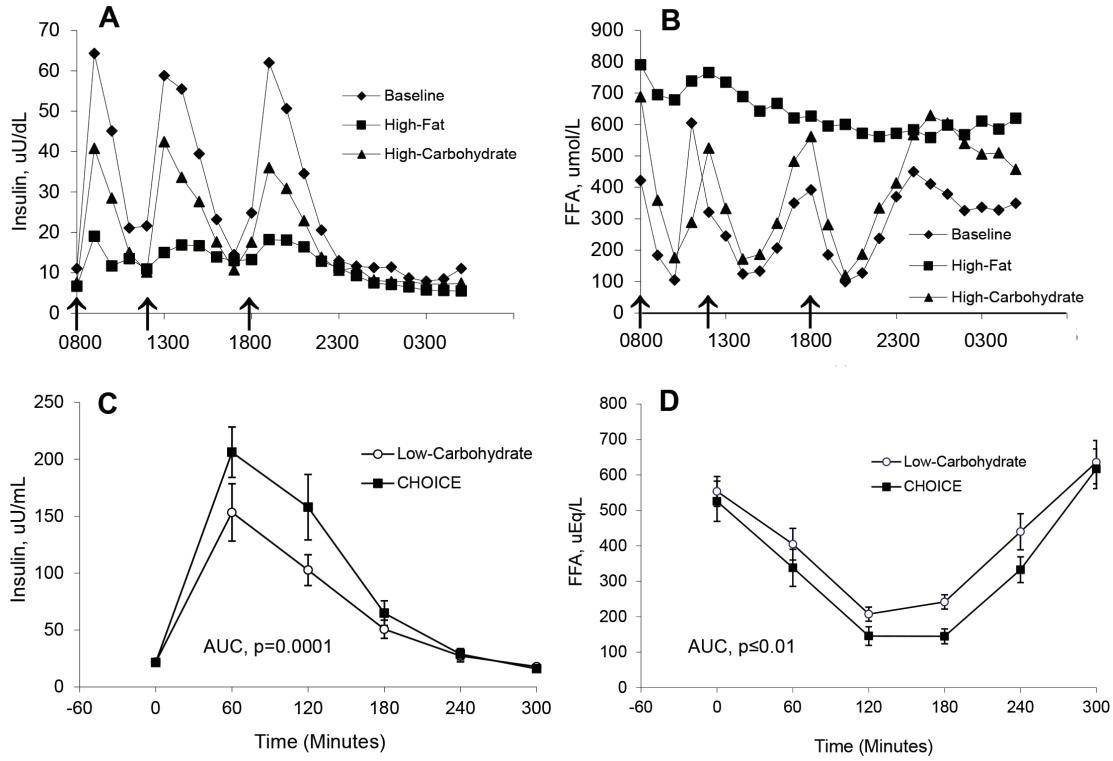

FIGURE 1. The case for complex carbohydrates in nutrition therapy for GDM: lessons from studies outside and within pregnancy. **A and B**. Thirty-two healthy, obese subjects were admitted to the Clinical Translational Research Center (CTRC) after a 12-hour fast for a 24-hour feeding study during which blood was drawn hourly and meals were administered at regimented times (indicated by arrows; baseline diet composition 55% carbohydrate/30% fat). They were then randomly assigned to follow a carbohydrate-restricted, high-fat diet (20 g carbohydrate/day; n = 16) or a calorie-restricted, low-fat/high-carbohydrate diet (55% carbohydrate/30% fat; n = 16) for 6 weeks. The 24-hour feeding study was repeated 6 weeks later with meals matching the randomized diet composition. Figure 1*A* shows reduced insulin secretion on the low-carbohydrate diet, and Figure 1*B* shows the parallel lack of FFA suppression by insulin and sustained elevated FFAs over 24 hours on the low-carbohydrate diet. Copyright American Society of Nutrition, 2010. Reprinted with permission from ref. 81. **C and D**. In a randomized, crossover study, 16 women with diet-controlled GDM followed a conventional low-carbohydrate diet (40% carbohydrate/45% fat) and the CHOICE diet (60% carbohydrate/25% fat) in random order for 3 days each (gestational week 31, 100% of calories provided, 2.5-day washout period between diets). On the fourth day of each diet treatment, women reported to the CTRC after an overnight fast. Baseline samples were collected, and a standardized breakfast test meal matching the randomized diet composition was consumed. Blood was drawn hourly for 5 hours. Figure 1*C* shows the postprandial insulin response on CHOICE, and Figure 1*D* shows a parallel better suppression of postprandial FFAs by CHOICE. The low-carbohydrate diet resulted in less insulin secretion (*C*) but worse suppression of lipolysis and increased postprandial FFAs (*D*). Copyright American Diabetes Association, 2014. Reprinted with permission from ref. 13.

within current treatment targets (13). Although more high-quality, randomized studies are needed, all of the evidence to date suggests that liberalization of complex carbohydrate in nutrition therapy for GDM meets management goals, may be effective in optimizing maternal and infant metabolic outcomes, and may help mitigate rising insulin resistance with advancing gestation in women with diet-controlled GDM.

Diet and Insulin Action: The Case for Complex Carbohydrates

Maternal insulin resistance is a key regulator of fetal nutrient exposure. Might it be possible to mitigate adipose tissue insulin resistance using nutrition therapy in GDM? If effective, this would result in optimal nutrient delivery and avoid the intrauterine overnutrition that programs aberrant growth patterns (42).

One of the greatest concerns in GDM is the risk for fetal LGA status and increased adiposity, historically linked to maternal hyperglycemia (25,71) and recently confirmed (72,73). Freinkel (51) described the intrauterine environment as an "incubation medium" shaped by all maternal nutrients—not only glucose. It is now understood that maternal glucose, lipids (triglycerides, FFAs), and amino acids are all potent fuels

for fetal growth. In normal late pregnancy, maternal insulin resistance increases to ensure rapidly increasing fetal-placental energy requirements and fetal growth. However, overweight and obese women who develop GDM enter pregnancy with chronic preexisting insulin resistance (74) and insufficient β-cell reserve (1,3). These women display worsened insulin resistance in skeletal muscle (75), liver, and adipose tissue (2,3,76,77) by the third trimester. Diets high in fat may promote insulin resistance in part through elevation of tumor necrosis factor α (78) and FFAs, resulting in impaired insulin signaling (76,79). Elevated FFAs may also promote a β-cell defect (76), and evidence suggests that higher pre- and early pregnancy intake of animal fats and cholesterol (80) are associated with increased risk for GDM, implicating an effect of dietary fat and cholesterol on exacerbation of insulin resistance. Thus, there is concern that a low-carbohydrate diet that facilitates an unbalanced increase in fat may actually worsen maternal insulin resistance in GDM, contributing to intrauterine overnutrition.

Insulin is a hormone with many functions beyond glucose control. It serves as a suppressor of FFA release (lipolysis) from stored triglyceride in adipose tissue. With better insulin action, there is better insulin suppression of lipolysis, less FFA exposure over time, and improved tissue sensitivity to insulin.

We have learned important lessons about diet and fuel metabolism from our controlled studies, both outside and within pregnancy. For example, after following a low-carbohydrate, high-fat diet (20 g carbohydrate/day) for 6 weeks, men and women secreted minimal insulin over 24 hours, resulting in an almost complete lack of FFA suppression by insulin (a marker of insulin resistance) and sustained elevated FFA levels over 24 hours (Figure 1A and B) (81). Our crossover study in diet-controlled GDM (13) showed that, after a controlled breakfast on the CHOICE diet, there was a higher insulin response, resulting in lower postprandial FFAs. The low-carbohydrate diet resulted in less insulin secretion (as seen in our nonpregnant participants) and worse suppression of lipolysis/increased postprandial FFAs (Figure C and D).

Humans are postprandial much of the day, and if the patterns seen in Figures 1*A* and *B* were similar in mothers with GDM, there would be high fetoplacental lipid exposure over 24 hours on a low-carbohydrate diet. In diet-controlled GDM, if the responses in Figures 1*C* and *D* were similar across meals, the low-carbohydrate diet would result in nearly 20% more lipid exposure than with the CHOICE diet. Importantly, early evidence also showed that 6–7 weeks of therapy with the CHOICE diet resulted in lower fasting glucose and FFAs, better insulin suppression of FFAs in adipose tissue, less adipose tissue inflammation, and a trend for less neonatal adiposity, all of which suggest better insulin action despite the rising insulin resistance of pregnancy (82). The case for including complex carbohydrates in nutrition therapy for GDM, then, is that, *if* the degree of maternal insulin resistance is a key regulator in controlling maternal glucose, lipids, and amino acids to the fetal-placental unit, *and* it can be lessened by balanced liberalization of complex nutrient-dense carbohydrate and reduced dietary fat, *then* excessive fetal growth and potential programming effects could be strongly modifiable by nutrition therapy in GDM.

Conclusion

Adherence to a low-carbohydrate diet is one of the most challenging components to therapy for GDM. It is possible that a less restrictive approach to nutrition therapy will lessen feelings of confinement in GDM. Although more high-quality, randomized trials are needed, there is evidence that a balanced liberalization of complex carbohydrate as part of an overall nutrient-dense eating plan in GDM meets treatment goals and may mitigate maternal adipose tissue insulin resistance, both of which may promote optimal metabolic outcomes for mothers and their offspring.

Acknowledgments

The author acknowledges the mentoring she has received from Linda A. Barbour, MD, Jacob (Jed) E. Friedman, PhD, and Robert H. Eckel, MD, and support received from the National Institutes of Health (NIH) National Center for Advancing Translational Sciences Colorado Clinical and Translational Research Institute (UL1 TR000154), the University of Colorado Center for Women's Health Research, the Colorado Program for Healthy Nutrition and Development, and the NIH National Institute for Diabetes and Digestive and Kidney Diseases (R01 DK101659).

Duality of Interest

No potential conflicts of interest relevant to this article were reported.

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