Gestational diabetes and nutritional recommendations

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Gestational Diabetes and Nutritional Recommendations

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The goals of medical nutrition therapy for gestational diabetes mellitus (GDM) are to meet the maternal and fetal nutritional needs, as well as to achieve and maintain optimal glycemic control. Nutrition requirements during pregnancy are similar for women with and without GDM. The American Diabetes Association and the American College of Obstetrics and Gynecology recommend nutrition therapy for GDM that emphasizes food choices to promote appropriate weight gain and normoglycemia without ketonuria, and moderate energy restriction for obese women. Current controversies in GDM nutrition therapy involve manipulation of dietary composition (amounts and types of carbohydrates and fats), gestational weight gain, and energy and carbohydrate restriction. Randomized controlled trials are needed to determine which dietary compositions and patterns promote normoglycemia as well as optimal maternal and infant outcomes. Until better evidence is available, nutrition therapy will remain a cornerstone of GDM management with potential benefits that cannot be fully realized in clinical practice.

Introduction

Despite the fact that nutrition therapy is hailed as the "cornerstone" of the treatment of gestational diabetes mellitus (GDM), current recommendations are based on inconclusive findings from observational studies and a few small intervention studies (both randomized and nonrandomized) of the effects of energy restriction and varying macronutrient intakes on maternal glycemia, ketonuria, weight gain, and perinatal outcomes [1–3,4•]. In nonpregnant diabetic patients, large, randomized clinical trials have definitively shown that individualized dietary prescriptions and exercise programs improve glycemic control, reduce microvascular complication rates, and promote weight loss [5,6]. During pregnancy, optimal growth and the health of the fetus and mother are foremost. Thus, weight loss strategies have limited use because maternal energy restriction may adversely affect fetal growth and development [1,7–9]. Current controversies in nutrition therapy for GDM involve manipulation of dietary composition (amounts and types of carbohydrates and fats), gestational weight gain, and energy restriction [2,10]. Based on a recent review of the Cochrane Databases, no randomized controlled trials comparing alternative management strategies for women with GDM in relation to perinatal outcomes met the quality criteria for review [11].

Overall goals of GDM nutrition are to achieve normoglycemia, adequate macronutrient dietary intake to avoid ketonuria and ketonemia [12], and appropriate gestational gain [4•,13]. Moderate calorie restriction in obese women (30% of estimated energy needs) with GDM may improve glycemic control without ketonemia and reduce maternal weight gain [14], but sample sizes have been inadequate to assess effects on perinatal outcomes. Some practitioners have recommended weight maintenance or limited weight gain for obese women with GDM [15]. Studies are limited to clinical observational studies, nonrandomized studies manipulating dietary constituents, and small, randomized interventions of moderate and severe calorie restriction [10]. Well-controlled randomized trials of dietary interventions for GDM are needed to provide scientific evidence as a basis for current nutrition recommendations.

The objectives of this article are to describe the nutritional recommendations for healthy pregnancy as they apply to GDM management, and specific recommendations for GDM nutrition therapy. Findings from both randomized and nonrandomized intervention trials of calorie restriction and dietary manipulation of carbohydrate levels are critically evaluated. The range of dietary intakes prescribed in usual clinical practice, average gestational weight gain, and prevalence of insulin use reported are examined. Although perinatal outcomes, such as infant birth weight, maternal and infant morbidity, and perinatal mortality are important, few studies of dietary intake have had adequate statistical power to examine these outcomes. Finally, nutrition management recommendations and future research directions are discussed.

Recommended Gestational Gain in Healthy Pregnancy and GDM Pregnancy

In large epidemiologic studies, low gestational gain (< 20 lb) has been associated with higher rates of low infant birth weight [13]. The influence of maternal gestational gain on

Table 1. Recommended gestational weight gain according to pregravid BMI categories

Pregravid weight category	BMI groups, kg/m^2	Weight gain recommended, *lb (kg)*
Underweight	< 19.8	28–40 (12.5–18)
Normal weight	19.8–26.0	25–35 (11.5–16)
Overweight	> 26.0–29.0	20–25 (7–11.5)
Obese	> 29.0	Minimum 15 (7)

BMI—body mass index.

infant birth weight is known to vary by maternal pregravid body size (body mass index [BMI]), and lower weight gains are recommended for women who are overweight or obese before conception, and higher weight gains for underweight women (Table 1). Dietary therapies for GDM management may result in lower gestational weight gain after therapy is initiated [16,17]. Yet, very few studies have evaluated the influence of gestational gain before and after diagnosis of GDM on infant birth weight and other perinatal outcomes. Recommendations from the 4th International Workshop-Conference on Gestational Diabetes Mellitus [1] incorporated the Institute of Medicine (IOM) recommendations on gestational weight gain [13] according to pregravid BMI (Table 1). Weight gain recommendations for normal pregnancy are also advised for GDM pregnancy.

Nutritional Recommendations for Healthy Pregnancy

Energy needs in pregnancy

The reported mean daily energy intake by pregnant women in the United States ranges from approximately 1500 to 2800 kcal/d [13]. An additional 300 kcal/d above nonpregnant levels is recommended during the second and third trimesters of pregnancy for women in developed countries [13]. However, evidence suggests that the energy costs vary considerably for the individual woman, depending on prepregnancy energy status and quality of living conditions during pregnancy [13,18,19]. Energy needs depend on body size, physical activity, climate, and other factors. For example, energy requirements of overweight pregnant women may be similar to those of normal weight pregnant women because basal metabolic rate may increase by as much as 20% to offset the deposition of additional fat stores [19]. The 1990 IOM report stated "Because of their larger body mass, obese women require energy intakes higher than those of normal weight women" for pregnancy [13]. However, differences in physical activity with body size influence actual energy requirements. Energy needs during pregnancy are based on total energy expenditure [20]. Protein needs may be met by intakes of 1.1 g/kg of body weight per day [20]. The recommended dietary allowance for carbohydrate intake during pregnancy has been established at 175 g/d [20]. The distribution of carbohydrate, protein, and fat calorie sources has not been specified for healthy pregnancy.

Nutritional Recommendations for GDM Pregnancy

Energy and carbohydrate levels

The clinical goals of medical nutrition therapy for GDM are twofold: to meet the maternal and fetal nutritional needs, and to achieve and maintain optimal glycemic control. Both the American Diabetes Association (ADA) and the American College of Obstetrics and Gynecology have issued recommendations for GDM management (Table 2). Most recently, recommendations emphasize that nutrition requirements during pregnancy are similar for women with and without diabetes, and GDM medical nutrition therapy should emphasize food choices to promote appropriate weight gain and normoglycemia without ketonuria [4•]. Specifically, nutrition and food recommendations are to be "determined and modified based on individual assessment and self–blood glucose monitoring data" [4•].

Until 1994, both nutrient and energy levels recommended for GDM were similar to those for nondiabetic pregnant women [21,22,25]. However, in 2000, the ADA recommended a 30% calorie restriction in obese women for the first time [23]. Current recommendations for GDM nutrition management (Table 2) [4•,24,26,27•] include modest energy restriction in obese women "(30% to 33% calorie restriction of estimated energy needs) based on evidence showing a reduction in hyperglycemia without any increase in ketonuria" [14,24] as long as energy intake is sufficient to maintain a desirable weight gain.

Carbohydrate levels recommended for GDM have mirrored those for nonpregnant persons with type 2 diabetes; carbohydrate levels were previously set at 55% to 60% of total energy intake with fat intake restricted to 30% of total energy [21]. Since 1994, no specific carbohydrate level has been recommended, but was to be based on "individual tolerance and treatment goals" for persons with diabetes [22,23]. In 2002, the ADA also recommended modest carbohydrate restriction (35% to 40% of kilocalories [kcal]) for GDM [4•]. This recommendation was based on limited observational evidence that high carbohydrate levels (55% compared to 40% of total energy) may be associated with deterioration in glycemic control, and accentuation of hyperinsulinemia among persons with type 2 diabetes [28] as well as pregnant women with GDM [29,30].

Table 2. Recommendations from ADA, ACOG, and experts on management for gestational diabetes*

Professional organization	Year	Daily calorie range	Meal and snacks	Amount of CHO, *kcal* %	PGBW, IBW %	Kcal prescribed, *kcal/kg*
ADA						
[21]	1986	Healthy pregnancy needs	Individualized	50–60	NR	35
[22]	1994	Healthy pregnancy needs	Individualized	Not specified: individualized based on glucose values	NR	NR
[23]	2000	For obese, 30% to 33% calorie restriction	Individualized	Consistent with maternal blood glucose goals	Adequate calories for needs of pregnancy; obese: BMI > 30	1800 kcal/d
[24]	2004	Modest kcal restriction (30%) as appropriate	3 meals and 2 to 4 snacks	Modest CHO restriction as appropriate	NR	NR
ACOG						
[25]	1994	2200–2400	3 meals + 1 snack	50–60 (303–330 g/d)	IBW groups: < 80, 80–120, 120–150, > 150	Based on PBW: 35–40, 30, 24, 12–15
[26]	2001	Modest kcal restriction (30% to 33%) in obese	Not specified	Not specified	NR	Based on PGBW: 30 (nonobese)
Gabbe and Graves [27•]	2003	2000–2200 1600–1800	Not specified	Not specified; complex, high fiber CHOs, exclude concentrated sweets	NR	30 kcal/kg IBW (nonobese) 25 kcal/kg (obese)

*Meals and snacks, total kilocalories, and CHO levels, and kcal per kilogram of body weight.
ACOG—American College of Obstetrics and Gynecology; ADA—American Diabetes Association; CHO—carbohydrate; IBW—ideal body weight; kcal—kilocalorie; NR—not reported; PBW—pregnant body weight; PGBW—pregravid body weight.

Evidence for Efficacy of Calorie Restriction in Obese GDM

Small randomized and nonrandomized clinical trials evaluating calorie restriction (Table 3) have shown that moderate restriction of energy for the obese woman with GDM (1700 to 1800 kcal/d) may improve maternal metabolic control without excessive ketonemia, but beneficial effects on infant size and other clinical outcomes have not been found due to inadequate statistical power based on sample sizes of 10 or less subjects per group [31,32,34]. Severe calorie restriction (reduction of kcal by 50%) has resulted in maternal weight loss, ketonuria, and ketonemia [33,36] and is, therefore, not advisable.

Weight loss and energy restriction, efficacious treatment strategies for overweight persons with type 2 diabetes, have been viewed with caution as a treatment for the pregnant woman with GDM. Ratner [3] states, "As with other forms of diabetes, diet therapy is the cornerstone of the intervention for the woman with GDM. Calorie restriction with weight loss is the preferred treatment modality for the nonpregnant patient..., but calorie restriction in GDM is one of the most contentious issues in the literature." In contrast, Langer [15] states, "Diet therapy means calorie restriction. It is well accepted that the diet should include 50% to 55% carbohydrate....", and "without weight loss, the moderate to severe hyperglycemic pregnant patient with diabetes will show no significant evidence of maternal glucose level reduction." These divergent viewpoints may be influenced by clinical practices, including goals of metabolic control, level of carbohydrate and energy restriction, methods of blood glucose monitoring, insulin therapy, and characteristics of patient populations including severity of glucose intolerance. In obese or overweight women with GDM, calorie restriction, which by definition results in total carbohydrate restriction, has been the prevailing approach evaluated in intervention studies (Table 3).

Severe calorie restriction by 50% or intakes in the range of 1200 to 1500 kcal/d result in weight loss, ketonuria, and improved blood glucose control [32,33,35,36]. Overall, moderate calorie restriction at levels of 1700 to 1800 kcal/d has resulted in lower maternal weight gain without ketonuria among obese women with GDM [14,32–34]. However, reduction in infant birth weight has not been demonstrated [14,31,32,37] because most studies have included 10 or fewer women per study group. The largest randomized trial to evaluate a 30% reduction in estimated energy needs included approximately 60 women in each group, but found no differences in perinatal outcomes, including infant morbidities and birth weight [37]. "Intensive dietary therapy" (defined by investigators as 1800 to 2000 kcal in the ADA diet) in one study of women with GDM reported macrosomia rates similar to a reference population [38].

In the 4th International Workshop-Conference on Gestational Diabetes Mellitus, recommendations supported the use of moderate calorie restriction to treat overweight women with GDM "as long as sufficient calories are provided to prevent excess fat catabolism and ketonuria" [1]. The committee did not reach agreement on a minimum calorie requirement, but suggested that prescriptions as low as "25 kcal/kg actual pregnant body weight (PBW) have been used with little risk of ketonuria."

Evidence for Dietary Manipulation of Macronutrients for GDM Pregnancy

Other "intensive" nutrition therapies for GDM (*eg*, total carbohydrate restriction, distribution of calories and carbohydrate over several small meals, high complex carbohydrate and fiber levels, and modification of food choices based on the glycemic index) have been examined in relatively few studies [2,39]. These nutrition therapies differ from energy restriction in that they provide adequate calories, but may restrict total and percentage of kilocalories from either carbohydrate or fat, alter the distribution of carbohydrate over meals and snacks, or emphasize low glycemic index and high fiber foods in the dietary prescriptions. Therapies that modify the amount, type, and distribution of carbohydrate or fat intake may reduce the acute demand on insulin action and production. These therapies may be particularly appropriate for nonobese women with GDM, for whom energy restriction is not recommended. Evidence from observational studies of women with GDM and from studies of persons with and without type 2 diabetes supports these strategies [28].

Distribution and amount of dietary carbohydrate

The goals of the dietary prescription include provision of sufficient calories and nutrients to meet maternal and fetal needs while achieving postprandial normoglycemia [23,39]. Intensive nutrition therapy refers to the "controlled intake of total amount, type, and distribution of carbohydrate consumed" while providing adequate calorie levels [2]. A few nonrandomized trials have examined the effect of varying levels and types of carbohydrate, fiber, or fat on blood glucose control, and the need for exogenous insulin as well as maternal and infant outcomes in GDM (Table 4). Randomized trials of sufficient size have not been conducted to evaluate these dietary therapies in women with GDM. One diet intervention study was located that randomized 27 women with GDM to a high carbohydrate diet or a high monounsaturated fatty acid (MUFA) diet, but found no differences in insulin sensitivity during 5 weeks [45].

The effects of the amount of carbohydrate intake on glycemia, insulin use, and infant outcomes in women with GDM have been examined in very few studies (Table 4). Peterson and Jovanovic-Peterson [46] reported a positive correlation between the glycemic response to a mixed meal and the percent of calories from carbohydrate [46]. In clinical practice, Jovanovic-Peterson and Peterson [29,30] reported that 50%

Table 3. Design and findings from intervention studies of dietary moderate and severe calorie restriction in the treatment of women with GDM

Study	Design: Weight groups; GDM status, *n*	Energy intake, *kcal/d*	Range of CHO g/d, *(CHO as % of kcal)*	Mean (SD) gestational gain, *kg*	Outcomes
Dornhorst *et al.* [31]	Clinic, observational:				No significant differences in high birth weight
	GDM: 35	1200–1800	150–225 (50)	4.6 ± 4.9	(> 4000 g) for GDM (*n* = 2, 6.0%) versus non-GDM
	Non GDM: 2337	NA		9.7 ± 5.3	(*n* = 178, 7.5%), or perinatal morbidity
Maresh *et al.* [32]	Alternate assignment:				
	GDM diet restrict: 10	1500–1800	120–150 (33)	0.7 kg/wk	No differences in infant outcomes. Decreased
	GDM diet restrict + insulin: 10	1800–2100	150–180 (33)	1.5 kg/wk	weight gain over treatment. Restricted diet alone:
	Non GDM control: 10	2800	285 (40)	1.1 kg/wk	increased ketonemia and glucose decrease not as great as with insulin
Knopp *et al.* [33]	Randomized (50% kcal):				
	Overweight GDM: 7	1200	150 (50)	NR	50% kcal reduction resulted in doubling of ketonuria
	Overweight GDM: 5	2400	300 (50)	NR	and improved glycemia by 10% to 20%
	Obese GDM, randomized				33% kcal reduction resulted in no marked ketonuria and improved glycemia and triglyceride levels
	Insulin: 3	2500	300 (50)	NR	
	33% kcal reduced: 3	1655	200 (50)	NR	
Algert *et al.* [34]	Nonrandomized:				Moderate kcal restriction of obese women with GDM
	Obese GDM: 22	1700–1800	212–225 (50–60)	10.6 ± 7.7	had lower maternal weight gain and kcal intake, higher
	Lean GDM: 31	2000–3000	250–370	13.3 ± 4.1	mean birth weight, and no ketonuria
	Control nonobese: 10	2282	NA	13.4 ± 3.5	
Gillmer *et al.* [35]	Randomized:			(4–5 wk gain):	
	GDM diet alone: 7	1500–1800	120–150 g	- 1.7 ± 2.6	Both diet and insulin-treated groups had similar increase
	GDM diet + insulin: 8	2100	180 g	+ 0.9 ± 2.4	in ketonemia. Weight loss in the kcal-restricted group
	Control: 8	NA	NA	+ 1.8 ± 1.4	
Magee *et al.* [36]	Randomized, obese:				50% kcal restricted: lower mean glucose, no change in
	GDM no kcal restriction: 5	2400	300 (50)	NR	fasting glucose, increased ketonuria, and ketonemia
	GDM 50% kcal restriction: 7	1200 (7 d)	150 (50)	NR	
Rae *et al.* [37]	Stratified randomization:	30% restriction:			Insulin therapy: 17.5% intervention vs 16.9% control,
	GDM intervention: 66	1590–1776	210–244 (51)	11.6 ± 1.3	but trend for lower insulin dose (23 vs 60 U).
	GDM control: 58	2010–2220	240–274 (46)	9.7 ± 1.5	No differences in ketonemia, ketonuria, blood glucose, pregnancy complications, birth weight, or neonatal complications

CHO—carbohydrate; GDM–gestational diabetes mellitus; kcal–kilocalorie; NA–not applicable; NR—not reported; SD–standard deviation.

Table 4. Summary of nutrition prescriptions and prevalence of insulin use reported in observational and nonrandomized studies of GDM and comparison of daily energy, CHO, and total CHO intakes based on Rxs for a standard nonobese woman*

Study	Sample / Study design / Location, y	*n*	Daily energy Rx	CHO intake, *kcal/d* %	Calculation for standard nonobese woman: Total *kcal/d*	Total *CHO, g/d*	CHO, *g/kcal*	Women treated with insulin, %
Kitzmiller *et al.* [40]	Prospective, clinical:							
	GDM	150	35 kcal/kg IBW	38–45	1925	200	0.104	30
	Non-GDM	305	NA					
	(USA: San Francisco, CA, year NR)							
Drexel *et al.* [41]	Prospective, clinical:							
	GDM	102	35 kcal/kg IBW	45–50	1925	240	0.125	86
	Non-GDM (matched)	102	NA					
	(Austria, year NR)							
Goldman *et al.* [42]	Prospective clinic:							
	GDM	150	34 kcal/kg DBW	40–50	1870	187	0.100	22
	Control (matched 2 to 1)	305	NA					
	(USA: San Francisco, CA, 1986–1989)							
Catalano *et al.* [17]	Retrospective cohort:							
	GDM	78	30–35 kcal/kg IBW	50	1650–1925	206–240	0.125	17
	Control (non-GDM)	312	NA					
	(USA: Vermont, 1985–1986)							
Langer *et al.* [43]	Population-based, prospective:							
	GDM conventional	1316	35 kcal/kg PBW	50–55	2450	306	0.125	36
	GDM intensified monitoring	1145	35 kcal/kg PBW	50–55	2450	306	0.125	66
	Control (non-GDM)	4922	NA					
	(USA: San Antonio, TX 1989–1993)							
Snyder *et al.* [16]	Retrospective chart review:							
	GDM clinic	353	35 kcal/kg IBW	34	1925	164	0.085	46
	(Quebec, Canada, 1978–1984)							
Jovanovic-Peterson and Peterson [29,30]	GDM clinics: nonrandomized:							
	Low calorie/CHO	30	30kcal/kg	30–40	2100	184	0.088	26
	High CHO	30	35 kcal/kg PBW	50–60	2450	336	0.137	50
	(USA: Santa Barbara, CA)							
Major *et al.* [44]	GDM clinics: nonrandomized:							
	Low CHO	21	25–35 kcal/kg IBW	42	1925	202	0.105	5
	High CHO	21	25–35 kcal/kg IBW	45–50	1925	229	0.119	33
	(USA: Irvine, CA, 1993–1994)							

*Kcal/d are based on a woman of standard height (5'3") and pregravid DBW or IBW of 55 kg, or actual early third trimester pregnant weight of 70 kg.
CHO—carbohydrate; DBW—pregravid desirable body weight; GDM—gestational diabetes mellitus; IBW—pregravid ideal body weight; NA—not available; NR—not reported; PBW—pregnant body weight; Rx—prescription.

of women required insulin therapy consuming a diet composed of 50% to 60% of energy from carbohydrate, but carbohydrate restriction to 30% to 40% of total kcal reduced insulin use by one half, to 26%. Major *et al.* [44] nonrandomly allocated two clinics of diet-controlled patients with GDM to either carbohydrate restriction (< 42% of kcal) or high carbohydrate (45% to 50% of total kcal). Restriction of carbohydrate resulted in lower mean postprandial blood glucose levels, fewer large-for-gestational-age infants, a lower rate of cesarean section from cephalopelvic disproportion, and reduced the frequency of insulin use to 5% compared with 33% in the high carbohydrate group [44]. This study provides the first evidence that carbohydrate restriction results in improved maternal glycemia as well as infant outcomes. Another observational study of 80 women with GDM found that higher carbohydrate intake was associated with decreased frequency of newborn macrosomia, but infant birth weight was not associated with fasting and 2-hour postprandial blood glucose values [47]. Controlled clinical trials in which women, not clinics, are randomized to the various diet treatments are needed to eliminate biases due to unmeasured confounding in the nonrandomized studies.

The 4th International Workshop also cited evidence that dietary interventions that limit carbohydrate intake to 35% to 45% of total kcal and use of complex carbohydrates has been effective in reducing postprandial hyperglycemia, although the report acknowledged that data relating either of these strategies to improved perinatal outcomes were not available at that time [1]. Since this 1998 report, data supporting any of these recommendations remain inadequate due to lack of controlled clinical trials with sufficient sample sizes to evaluate maternal and infant clinical outcomes.

Type of fats and carbohydrate

Carbohydrate restriction results in increased percentages of total kcal from protein and fat to meet overall energy needs. Even less information is available on the effect of type of dietary fats and carbohydrates on blood glucose metabolic control in women with GDM. The effects of dietary constituents on glycemic control in nonpregnant type 2 diabetic patients provide evidence for beneficial effects of low versus high glycemic foods and MUFAs versus polyunsaturated fatty acids in the diet. In women with GDM, a randomized crossover study (n = 10) found that adding saturated fatty acids compared with MUFAs resulted in lower postprandial glucose and insulin responses [48]. Further research is needed on the effects of dietary composition and amounts of fats and carbohydrates on glycemia and insulin sensitivity in women with GDM.

Comparison of Dietary Prescriptions in Clinical Practice for GDM

To describe the dietary management used in clinical practice, observational studies of women with GDM were selected that included sample sizes of 30 or more, were published between 1988 and 2001, and reported the following: 1) calorie prescriptions based on PBW, pregravid desirable body weight (DBW), or ideal body weight (IBW); 2) percent of energy as carbohydrate; and 3) prevalence of insulin therapy for the study sample [16,17,29,30,40–44]. The calorie and carbohydrate levels prescribed in these studies were standardized for comparison purposes based on a nonobese woman who is 63 inches tall and has a pregravid ideal weight of 55 kg or actual weight of 70 kg during late pregnancy (Table 4). Standardized calorie levels based on clinical practice prescriptions varied by kcal per kilogram of body weight and whether pregravid ideal or actual pregnancy weight criteria were used to calculate the energy prescription. Obese women with GDM (standard height of 63 inches and actual pregravid weight of 83 kg or actual weight of 88 kg during late pregnancy) were generally prescribed lower calorie levels per kilogram of body weight than nonobese women; ranging from 24 to 28 kcal/kg DBW, or 12 to 15 kcal/kg actual PBW (data not shown).

Calorie and carbohydrate levels

The GDM calorie prescriptions for nonobese women were similar across the reports. Approximately 2000 kcal/d were prescribed, with the exception of two studies where estimates were 2450 kcal for a nonobese woman of standard weight and height [30,43]. In another study, 1650 kcal was prescribed as a lower level for nonobese women [17]. The calorie levels prescribed for an obese woman were lower and more variable across studies; ranging from 1350 to 2100 kcal/d (data not shown). The large differences are related to the use of pregravid IBW versus actual PBW to calculate the calorie (kcal) prescriptions. For example, use of pregravid IBW without adjustment for the excess body weight results in a low calorie prescription for the obese woman. These low calorie prescriptions are likely to result in significant ketonuria and weight loss. Some clinicians have specified a lower limit of 1500 kcal/d during pregnancy for obese women [49].

Total carbohydrate intake in grams per day (g/d) was calculated based on kcal levels for nonobese and obese women of standard weight and height. Carbohydrate levels prescribed varied considerably across studies for both nonobese and obese women, due to differences in both calorie levels and the percentage of total energy from carbohydrate. For a nonobese woman, restriction of total kcal from carbohydrate to 40% or less resulted in dietary carbohydrate levels prescribed that ranged from a total of 172 to 184 g/d. Carbohydrate prescriptions in the range of 50% to 60% of total kcal resulted in 50% to 70% higher dietary carbohydrate levels ranging from 240 to 300 g/d. For the obese woman, carbohydrate levels were lower, ranging from 118 to 265 g/d, largely due to the lower kcal prescription per kilogram of body weight for similar percentages of total energy as carbohydrate (data not shown).

These sample calculations demonstrate the enormous variability in the composition of nutrition therapies,

including carbohydrate load, that must be metabolized. Variation in dietary prescription is one explanation for the inconsistent findings about the impact of diet therapy on metabolic control and other clinical indicators based on the large disparity in dietary energy and carbohydrate levels. In theory, higher intakes of carbohydrate per kilogram of body weight for a constant level of insulin resistance result in higher postprandial blood glucose excursions and, therefore, demand higher insulin production. Depending on the week of gestation and the degree of glucose intolerance for the individual woman, the need for insulin therapy may be determined, to a large extent, by postprandial glycemic excursion following the dietary carbohydrate load, particularly in women with normal fasting blood glucose levels (< 95 mg/dL). Differences in calorie prescriptions, blood glucose monitoring, and criteria for initiation of insulin therapy may be other factors.

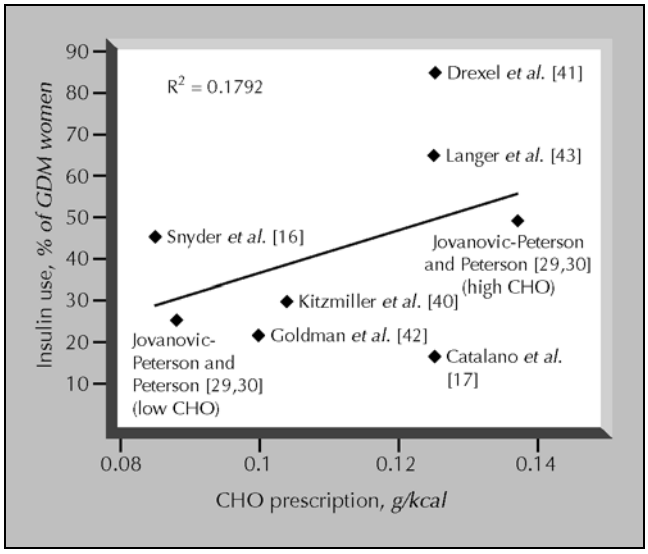

Figure 1. The prescribed carbohydrate (CHO) intake in grams per kilocalorie and the prevalence of insulin use in women with gestational diabetes mellitus (GDM) from published studies.

Prevalence of insulin use

Approximately 30% of women with GDM require insulin therapy during gestation [50]. A few nonrandomized studies have shown a smaller proportion requiring insulin for restricted carbohydrate intake. In selected clinical studies (Table 4), the proportion of women with GDM treated with insulin increases with both carbohydrate intake (grams per kcal) and percentage of total energy as carbohydrate prescribed. In Figure 1, the data from these studies are plotted and a positive correlation is shown between the level of carbohydrate prescribed (grams of carbohydrate per kcal) and the percentage of women with GDM treated with insulin therapy. Because of the ecologic nature of these data, many other individual level factors may account for the relationships, such as severity of glucose intolerance, degree of maternal obesity, differing goals for glycemic control, criteria for initiation of insulin therapy, and variation in dietary adherence within the study samples. Nonetheless, higher dietary carbohydrate prescriptions may be associated with a higher proportion of subjects who require insulin treatment during pregnancy, as reported in nonrandomized studies [29,30] of low versus high carbohydrate levels (Table 4). The need for insulin therapy in GDM pregnancy also depends on the severity of glucose intolerance. In one study, 54% of women (n = 147) with fasting glucose above 95 mg/dL versus 30% of women (n = 122) with fasting glucose at or below 95 mg/dL required insulin therapy [51].

Energy needs based on actual dietary intakes for women with GDM

Snyder *et al.* [16] estimated the actual mean calorie intake by body size for underweight, normal, overweight, and obese women with GDM, which ranged from 2034 ± 122 to 2072 ± 120 kcal/d (P = 0.075). However, the intakes expressed as per kilogram of pregravid weight showed significant differences. Daily calorie levels ranged from 42.5 kcal/kg for the underweight woman, down to 23.9 kcal/kg for the obese women (P < 0.001). Similarly, Butte [52] estimated energy needs based on the ratio of 24-hour total energy expenditure to basal metabolic rate in women with GDM at 32 kcal/kg/d based on a mean body weight of 89.7 kg.

Evidence-based Recommendations

Based on limited scientific evidence, recommendations for GDM nutrition therapy remain broad; provision of adequate calories to achieve weight gain goals and prevent ketonuria, provision of carbohydrate as a percentage of calories to promote normoglycemia for the individual (range of 35% to 50%), and distribution of daily carbohydrate over six small meals with a lower carbohydrate intake at breakfast [2]. The individual nutrition prescription is based on the maternal pregravid weight status, level of glycemic control, and the need for insulin therapy. Overweight women with GDM may benefit from moderate calorie restriction [4•]. Calorie prescriptions per kilogram of actual pregravid body weight may be more realistic, based on levels reported by Snyder *et al.* [16]. Postprandial blood glucose levels have been more closely related to fetal risks than fasting levels, which supports the recommendation that frequent self–blood glucose monitoring may be useful for the detection of deteriorating blood glucose control and the initiation of more intensive therapy, including insulin [1,43]. The clinical management and nutrition therapy for GDM should be modified on an ongoing basis to achieve clinical goals. Gestational weight gain for overweight women may be limited to a total of 9 kg, and for the very obese women (BMI > 30) a modest total gain of 7 kg or weight maintenance during pregnancy under the guidance of a registered dietitian may be advised.

Conclusions

Nutrition recommendations for GDM pregnancy, including gestational gain, calorie intake, and macronutrient composition and distribution, are based on insufficient scientific evidence about effects on maternal glycemic control and perinatal outcomes. Some evidence from randomized trials supports the recommendation for moderate calorie restriction in obese women; however, effects on perinatal outcomes are not known. Observational and nonrandomized reports suggest that maternal glycemia is improved with lower carbohydrate intakes, but the evidence is very weak. Currently, little is known about the effects of various GDM nutrition therapies on perinatal outcomes and long-term maternal health status (*eg,* risk of type 2 diabetes), including postpartum weight retention.

In the absence of evidence from controlled randomized clinical trials regarding the efficacy of various dietary prescriptions for the management of GDM, clinicians must focus on strategies that apparently result in optimal maternal blood glucose control based on empiric methods. In clinical practice, individualized diet therapy for GDM is based on ongoing evaluation of clinical indicators (*eg,* fasting, pre- and postprandial blood glucose measurements, self-monitoring of fasting ketonuria), pregravid maternal body size, gestational weight gain goals, and appropriate levels of physical activity. In addition, insulin therapy may be necessary if nutrition and exercise therapies are unable to achieve adequate metabolic control. Although there is a general consensus that moderate calorie restriction may be effective in the management of the obese GDM [24], it is not clearly established whether the effect is partially due to the limitation of total carbohydrate as a consequence of energy restriction. The effectiveness of other nutrition therapies for GDM (*eg,* macronutrient composition, glycemic load, or 24-hour calorie distribution) is not established. The rate of third trimester gestational gain may be slowed significantly after initiation of nutrition therapy [16], such that the effects of GDM therapy on maternal gestational gain may influence the relationship of maternal pregravid body size to infant birth weight of among women with GDM [17].

Large randomized trials are needed to compare intensive dietary therapies (carbohydrate restriction and types of macronutrients) to evaluate their influence on maternal glycemia and ketonemia, gestational weight gain, insulin therapy, and perinatal outcomes (*eg,* newborn macrosomia, neonatal hypoglycemia, cesarean section, and other complications) among both nonobese and obese women with GDM [10]. Until rigorous scientific investigations are undertaken to determine dietary compositions that promote normoglycemia, nutrition therapy will remain a cornerstone of GDM management with potential benefits that cannot be fully realized in clinical practice.

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References and Recommended Reading

Papers of particular interest, published recently, have been highlighted as:

- • Of importance
- •• Of major importance

1. Metzger BE, Coustan DR: **Summary and recommendations of the Fourth International Workshop-Conference on Gestational Diabetes Mellitus. The Organizing Committee.** *Diabetes Care* 1998, **21(suppl 2):**B161–B167.
2. Gunderson EP: **Intensive nutrition therapy for gestational diabetes. Rationale and current issues.** *Diabetes Care* 1997, **20:**221–226.
3. Ratner RE: **Clinical review 47: Gestational diabetes mellitus: after three international workshops do we know how to diagnose and manage it yet?** *J Clin Endocrinol Metab* 1993, **77:**1–4.
4. • American Diabetes Association: **Evidence-based nutrition principles and recommendations for the treatment and prevention of diabetes and related complications.** *Diabetes Care* 2002, **25:**202–212.

New recommendations and rationale for GDM, including calorie and carbohydrate restriction.

5. Tuomilehto J, Lindstrom J, Eriksson JG, *et al.*: **Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance.** *N Engl J Med* 2001, **344:**1343–1350.
6. **The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes mellitus. The Diabetes Control and Complications Trial Research Group [no authors listed].** *N Engl J Med* 1993, **329:**977–986.
7. Buchanan TA, Metzger BE, Freinkel N: **Accelerated starvation in late pregnancy: a comparison between obese women with and without gestational diabetes mellitus.** *Am J Obstet Gynecol* 1990, **162:**1015–1020.
8. Metzger BE, Freinkel N: **Accelerated starvation in pregnancy: implications for dietary treatment of obesity and gestational diabetes mellitus.** *Biol Neonate* 1987, **51:**78–85.
9. Franz MJ, Bantle JP, Beebe CA, *et al.*: **Evidence-based nutrition principles and recommendations for the treatment and prevention of diabetes and related complications.** *Diabetes Care* 2002, **25:**148–198.
10. Dornhorst A, Frost G: **The principles of dietary management of gestational diabetes: reflection on current evidence.** *J Hum Nutr Diet* 2002, **15:**145–156.
11. Tuffnell DJ, West J, Walkinshaw SA: **Treatments for gestational diabetes and impaired glucose tolerance in pregnancy.** *Cochrane Database Syst Rev* 2003, **(3)**CD003395.
12. Naeye RL: **The outcome of diabetic pregnancies: a prospective study.** *Ciba Found Symp* 1978, 227–241.
13. Institute of Medicine: *Nutrition During Pregnancy.* Washington, DC: National Academy of Sciences; 1990.
14. Franz MJ, Horton ES Sr, Bantle JP, *et al.*: **Nutrition principles for the management of diabetes and related complications.** *Diabetes Care* 1994, **17:**490–518.
15. Langer O: **Management of gestational diabetes.** *Clin Perinatol* 1993, **20:**603–617.
16. Snyder J, Gray-Donald K, Koski KG: **Predictors of infant birth weight in gestational diabetes.** *Am J Clin Nutr* 1994, **59:**1409–1414.
17. Catalano PM, Roman NM, Tyzbir ED, *et al.*: **Weight gain in women with gestational diabetes.** *Obstet Gynecol* 1993, **81:**523–528.

18. Durnin JV: **Energy requirements of pregnancy: an integration of the longitudinal data from the five-country study.** *Lancet* 1987, **2:**1131–1133.
19. King JC: **Physiology of pregnancy and nutrient metabolism.** *Am J Clin Nutr* 2000, **71:**1218S–1225S.
20. Food and Nutrition Board, Institute of Medicine: *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids.*Washington, DC: The National Academies Press; 2002.
21. **Gestational diabetes mellitus. American Diabetes Association [no authors listed].** *Diabetes Care* 1986, **9:**430–431.
22. **Nutrition recommendations and principles for people with diabetes mellitus [no authors listed].** *Diabetes Care* 1994, **17:**519–522.
23. American Diabetes Association: **Gestational diabetes mellitus.** *Diabetes Care* 2000, **23(suppl 1):**S77–S79.
24. American Diabetes Association: **Nutrition principles and recommendations in diabetes.** *Diabetes Care* 2004, **27(suppl 1):**S36–S46.
25. American College of Obstetricians and Gynecologists: *Diabetes and Pregnancy. ACOG Technical Bulletin #200.* Washington, DC: 1994.
26. American College of Obstetricians and Gynecologists Committee on Practice Bulletins—Obstetrics: **ACOG Practice Bulletin. Clinical management guidelines for obstetrician-gynecologists. Number 30, September 2001 (replaces Technical Bulletin Number 200, December 1994). Gestational diabetes.** *Obstet Gynecol* 2001, **98:**525–538.
27.• Gabbe SG, Graves CR: **Management of diabetes mellitus complicating pregnancy.** *Obstet Gynecol* 2003, **102:**857–868.
Review of the evidence and current recommendations for medical and nutritional management of GDM.
28. Garg A, Bantle JP, Henry RR, *et al.*: **Effects of varying carbohydrate content of diet in patients with non-insulin-dependent diabetes mellitus.** *JAMA* 1994, **271:**1421–1428.
29. Jovanovic-Peterson L, Peterson CM: **Dietary manipulation as a primary treatment strategy for pregnancies complicated by diabetes.** *J Am Coll Nutr* 1990, **9:**320–325.
30. Jovanovic-Peterson L, Peterson CM: **Rationale for prevention and treatment of glucose-mediated macrosomia: a protocol for gestational diabetes.** *Endocr Pract* 1996, **2:**118–129.
31. Dornhorst A, Nicholls JS, Probst F, *et al.*: **Calorie restriction for treatment of gestational diabetes.** *Diabetes* 1991, **40(suppl 2):**161–164.
32. Maresh M, Gillmer MD, Beard RW, *et al.*: **The effect of diet and insulin on metabolic profiles of women with gestational diabetes mellitus.** *Diabetes* 1985, **34(suppl 2):**88–93.
33. Knopp RH, Magee MS, Raisys V, Benedetti T: **Metabolic effects of hypocaloric diets in management of gestational diabetes.** *Diabetes* 1991, **40(suppl 2):**165–171.
34. Algert S, Shragg P, Hollingsworth DR: **Moderate caloric restriction in obese women with gestational diabetes.** *Obstet Gynecol* 1985, **65:**487–491.
35. Gillmer MD, Maresh M, Beard RW, *et al.*: **Low energy diets in the treatment of gestational diabetes.** *Acta Endocrinol Suppl (Copenh)* 1986, **277:**44–49.
36. Magee MS, Knopp RH, Benedetti TJ: **Metabolic effects of 1200-kcal diet in obese pregnant women with gestational diabetes.** *Diabetes* 1990, **39:**234–240.
37. Rae A, Bond D, Evans S, *et al.*: **A randomised controlled trial of dietary energy restriction in the management of obese women with gestational diabetes.** *Aust N Z J Obstet Gynaecol* 2000, **40:**416–422.
38. Wechter DJ, Kaufmann RC, Amankwah KS, *et al.*: **Prevention of neonatal macrosomia in gestational diabetes by the use of intensive dietary therapy and home glucose monitoring.** *Am J Perinatol* 1991, **8:**131–134.
39. Jovanovic L: **American Diabetes Association's Fourth International Workshop-Conference on Gestational Diabetes Mellitus: summary and discussion. Therapeutic interventions.** *Diabetes Care* 1998, **21(suppl 2):**B131–B137.
40. Kitzmiller JL, Hoedt LA, Gunderson EP, *et al.*: **Macrosomia and birth trauma in infants of diet treated gestational diabetic women.** In *Gestational Diabetes.* Edited by Weiss P, Coustan DR. New York: Springer-Verlag; 1988:160–166.
41. Drexel H, Bichler A, Sailer S, *et al.*: **Prevention of perinatal morbidity by tight metabolic control in gestational diabetes mellitus.** *Diabetes Care* 1988, **11:**761–768.
42. Goldman M, Kitzmiller JL, Abrams B, *et al.*: **Obstetric complications with GDM. Effects of maternal weight.** *Diabetes* 1991, **40(suppl 2):**79–82.
43. Langer O, Rodriguez DA, Xenakis EM, *et al.*: **Intensified versus conventional management of gestational diabetes.** *Am J Obstet Gynecol* 1994, **170:**1036–1046.
44. Major CA, Henry MJ, De Veciana M, Morgan MA: **The effects of carbohydrate restriction in patients with diet-controlled gestational diabetes.** *Obstet Gynecol* 1998, **91:**600–604.
45. Lauszus FF, Rasmussen OW, Henriksen JE, *et al.*: **Effect of a high monounsaturated fatty acid diet on blood pressure and glucose metabolism in women with gestational diabetes mellitus.** *Eur J Clin Nutr* 2001, **55:**436–443.
46. Peterson CM, Jovanovic-Peterson L: **Percentage of carbohydrate and glycemic response to breakfast, lunch, and dinner in women with gestational diabetes.** *Diabetes* 1991, **40(suppl 2):**172–174.
47. Romon M, Nuttens MC, Vambergue A, *et al.*: **Higher carbohydrate intake is associated with decreased incidence of newborn macrosomia in women with gestational diabetes.** *J Am Diet Assoc* 2001, **101:**897–902.
48. Ilic S, Jovanovic L, Pettitt DJ: **Comparison of the effect of saturated and monounsaturated fat on postprandial plasma glucose and insulin concentration in women with gestational diabetes mellitus.** *Am J Perinatol* 1999, **16:**489–495.
49. Hollingsworth DR, Ney DM: **Caloric restriction in pregnant diabetic women: a review of maternal obesity, glucose and insulin relationships as investigated at the University of California, San Diego.** *J Am Coll Nutr* 1992, **11:**251–258.
50. Landon MB, Gabbe SG, Sachs L: **Management of diabetes mellitus and pregnancy: a survey of obstetricians and maternal-fetal specialists.** *Obstet Gynecol* 1990, **75:**635–640.
51. McFarland MB, Langer O, Conway DL, Berkus MD: **Dietary therapy for gestational diabetes: how long is long enough?** *Obstet Gynecol* 1999, **93:**978–982.
52. Butte NF: **Carbohydrate and lipid metabolism in pregnancy: normal compared with gestational diabetes mellitus.** *Am J Clin Nutr* 2000, **71:**1256S–1261S.