Clinical Pediatrics
Volume XX Number X
Month XXXX xx-xx

10.1177/0009922809332585
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A 6-Month, Office-Based, Low-Carbohydrate Diet Intervention in Obese Teens

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Background. Previous studies have shown the success of a low-carbohydrate diet (LCD) in adults. In one study, the LCD has also been shown as safe and effective in teens, the study period was only 12 weeks. Furthermore, there is no information on whether the LCD is a practical intervention in a pediatric office setting. *Objective*. The object of this study was to demonstrate the effectiveness of a LCD in obese children in a primary care pediatric setting. *Design/Methods*. The study was done in 11 community pediatric practices. Children ages 12 to 18 years with a body mass index (BMI) greater than 95th percentile were put on a LCD of less than 50 grams of carbohydrate daily. *Results*. A total of 38 of the 63 teens finished the 6-month study and 32 (84%) lost weight (range from a gain of 5.5 kg to a loss of 23.9 kg). There was also a significant decrease in mean BMI (34.9 to 32.5). *Conclusions*. The LCD appears to an effective and practical office-based intervention in obese teenagers.

Keywords: adolescents; low-carbohydrate diet; obesity

Childhood obesity is a now a major health problem; over 15% of American children are obese by age 12.[1] This rate represents a 3-fold increase in obesity over the past 30 years. Although many dietary interventions have been proposed and have gained popularity in the lay press, only a few have been submitted to scientific scrutiny.[2] This has led to frustration among families of obese children and their practitioners in determining effective options.

Although low-carbohydrate dieting was described over 100 years ago, it was popularized in the 1970s.[3] Brehm et al studied the low-carbohydrate diet (LCD) compared to low-fat dieting in a randomized, controlled trial in obese women.[4] In this study, there was about twice the weight loss in the LCD group, and lipid parameters improved in the LCD group over a 6-month period.[4] Several other studies suggest the LCD is both safe and effective in adults.[5-10]

Sondike and colleagues reported the first documented trial of a LCD in adolescents. They randomized 30 overweight teens comparing an LCD to a low-calorie, low-fat diet and saw greater weight loss in the LCD group and improvement in lipid parameters over a 12 week period.[11] Although an LCD may be an attractive study to practitioners treating obese teens, as the rules of the diet are relatively straightforward and overall food intake is not restricted, there is no information whether the diet is a practical intervention in the office setting. With our study, we describe an LCD intervention in obese adolescents in the pediatric office setting over a 6-month period.

Methods

Seventy-one subjects, 12 to 18 years of age with a body mass index (BMI) in the 95th percentile or more for age, were recruited from the practices of the

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Cincinnati Pediatric Research Group (CPRG). The CPRG is a practiced-based research network of 45 practitioners in 25 practices in a midwestern community of 1.8 million people. Eleven of the CPRG practitioners chose to participate in this study. Enrollment was based on an anticipated sample size of 34 patients with a 5% predicted reduction in weight (power = 80, $\alpha = .05$) and an attrition rate of 50%. A child was excluded if:

1. the child had participated in obesity or nutrition study within 6 months of enrollment
2. there was an inability by the child or parent/guardian to understand the study
3. the child had a chronic condition associated with obesity (eg, Prader-Willi syndrome)
4. the child had diabetes mellitus
5. the child was on chronic medications known to cause weight gain (eg, corticosteroids)
6. the child had an abnormal thyroid or kidney function test
7. the child had a cholesterol level greater than 250 mg/dL or triglycerides greater than 175 mg/dL

At entry, the child and family met with the study dietician and their regular physician or pediatric nurse practitioner. It was suggested that the baseline laboratory evaluation include a complete blood count (CBC); renal profile; thyroid stimulating hormone level; fasting glucose; fasting insulin; fasting total cholesterol, high-density lipoprotein (HDL), low-density lipoprotein (LDL), and triglyceride levels; and a urine dipstick. The study dietician contacted the family by phone after 3 to 5 days in the study to answer any questions about the diet and to monitor how the teen was doing on the diet.

The study participants met the same study dietician at again at 2 weeks, 1 month, 2 months, 4 months, and 6 months after entering the study. They also met with their regular pediatric provider again at 2 months, 4 months, and 6 months. Before each of the follow-up visits to the study dietician, the participants were asked to complete a three day diary of dietary intake. Practitioners were asked to obtain the following laboratory studies on participants at 6 months: CBC; renal profile; fasting serum glucose; fasting insulin level; and total cholesterol, HDL, LDL, and triglyceride levels. The Rosenberg Self-Esteem Survey was completed by participants at entry, at 2 months, and at 6 months. This scale was selected because of its ease of administration and its established validity in the study age group.[12] The teens and their guardians were counseled on improving physical activity and on the LCD. Participants and their parents were asked to complete an 8-question survey at the end of the 6-month study.

The Diet

The teens and their guardians were instructed to restrict the teen's carbohydrate intake to 50 g per day. The families were counseled not to limit their carbohydrate intake to less than 20 g per day. They also were told there was no restriction on fat or protein intake. If a participant's BMI dropped to less than the 85th percentile for age during the study, the teen and family were instructed to liberalize carbohydrate intake. The families were given instructional aids, which included the book *Atkins for Life*.[13]

Statistics

The data were entered into Microsoft Excel and then transferred to SAS (Version 9, SAS Institute, Cary, NC) for analysis. The data were initially checked for outliers and distribution so that any necessary transformations could be made prior to analysis. A generalized mixed model approach was used to assess change over time for the following outcome variables of interest: dietary intake, weight and BMI, and self-esteem.

The study was approved by the Cincinnati Children's Hospital and the St. Luke Hospitals of Northern Kentucky Institutional Review Boards. Written informed consent was obtained from each teen's legal guardian and verbal assent was obtained from the child.

Results

Sixty-seven teens who met entry criteria were recruited in the 11 practices. Fifty-three (79%) were female, 50 (75%) were white, 15 (22%) were black, and 1 (1.5%) was Hispanic. The mean age of the participants was 14.5 years with a standard deviation 1.71 years and a range of 12 to 18 years. Sixty-three of 67 (94%) participants had at least 2 study visits and were used for study analysis. In all, 32 of 38 teens lost weight on the diet, 5 gained weight, and 1 participant's weight was unchanged. The most weight lost was 23.9 kg and the most gained 5.5 kg.

Table 1 summarizes physical parameters, caloric intake, and self-esteem scores. Table 2 summarizes the group's compliance for visits, and Table 3 illustrates compliance in limiting carbohydrates. There were

Table 1. Change over Time of Nutrient Intake Physical Parameters – Reported as Mean (sem)

Visit	Baseline	Week 2	Month 1	Month 2	Month 4	Month 6
N	63	57	54	53	40	38
Calories[a]	2401 (94)	1184 (94)	1140 (99)	1108 (98)	1187 (101)	1153 (114)
Carbohydrates[a]	324 (14)	52 (15)	57 (15)	46 (15)	64 (16)	62 (17)
Fats	87 (6)	72 (6)	70 (6)	69 (6)	76 96	68 (7)
Protein	84 (5)	83 (5)	82 (5)	71 (5)	72 (5)	73 (6)
Height (cm)[b]	163.61 (0.94)	163.53 (0.94)	163.77 (0.94)	164.07 (0.94)	164.59 (0.94)	164.83 (0.94)
Weight (kg)[c]	93.4 (2.3)	91.6 (2.3)	90.8 (2.3)	89.6 (2.3)	88.5 (2.3)	88.3 (2.3)
BMI [c]	34.9 (0.81)	34.2 (0.81)	33.8 (0.81)	33.2 (0.81)	32.7 (0.81)	32.5 (0.81)
BMI percentile [b]	98.4 (0.25)	98.2 (0.25)	97.9 (0.25)	97.6 (0.25)	97.1 (0.26)	97.1 (0.26)
Self-esteem[d] (low score is better self-esteem)	16.6 (0.52)			15.9 (0.54)		15.0 (0.61)
BMI z score [c]	2.23 (0.04)	2.19 (0.04)	2.16 (0.04)	2.11 (0.04)	2.06 (0.04)	2.05 (0.04)

Note: BMI, body mass index; sem, standard error of the mean.
a. Significant changes from baseline to other intervals ($P < .05$)
b. Significant changes in 2 month intervals ($P < .05$)
c. Significant decrease for all but 4 to 6 months ($P < .005$)
d. Significant decrease baseline to 6 months ($P < .05$)

Table 2. Compliance with Visits (N = 63)

Number of Visits	N (%) of Subjects
Baseline	63 (100)
Week 2	57 (90)
Month 1	54 (86)
Month 2	53 (84)
Month 4	40 (63)
Month 6	38 (60)

significant decreases in caloric intake, weight, BMI, and carbohydrate intake. Height increased during the study period, and self-esteem, as a measure of the Rosenberg scale, showed improvement. Reported total fat and protein intake did not change significantly during the study period. Twenty-three teens left the study voluntarily, and 2 left for symptoms possibly related to the diet. One teen complained of fatigue and the other of muscle aches, and both had resolution of symptoms when they stopped the diet.

Thirty-seven teens completed the end of study questionnaire. Forty-six percent reported attempted dieting in the past, and 54% felt the LCD was much easier to follow. Ninety-four percent felt the diet was somewhat or very successful, and 68% thought the results were much better with the LCD than other diets. Thirty-eight percent of participants planned on remaining on the LCD beyond 1 year.

The results of laboratory testing are summarized in Table 4. Hematocrit and hemoglobin were noted to have a significant increase over the study period. Although lipid parameters showed no significant change, compliance was only 37% for being able to obtain the laboratory studies.

Discussion

In this report we describe the experience of the largest cohort to date of obese teens put on an LCD. Although previous studies in adults had shown the diet to be safe and effective, studies in teens are limited and short term. The majority of participants lost weight, had a decrease in BMI, and found the diet acceptable.

Studies of LCDs demonstrate overall improvement in lipid profile when compared to the more traditional approach of a low fat diet. In separate studies, Seshadri and Peairs showed both an improvement in lipid profile and inflammatory markers.[14,15] Still, some experts are concerned that unlimited fat and protein in the diet may have an adverse effect.[16] Brehm et al showed that those on an LCD ate fewer calories than at baseline and had a modest increase in protein intake of about 17%, little change in total fat intake, and a marked decrease of total carbohydrate intake of 49%.[4] We demonstrated a similar phenomenon in that by self-report there were decreases in total fat and protein intake of 22% and 14%, respectively. Carbohydrate intake decreased by 87% and overall calories by 52%. Although the

Table 3. Compliance with Recommended Carbohydrate Grams in Diet (% is calculated for categories based on non-missing data) (n[%])

Visit	N	Missing	< 50	50–59	60–69	≥ 70
Baseline	63	19	0 (0)	0 (0)	0 (0)	44 (100)
Week 2	57	16	19 (46.3)	7 (17.1)	6 (14.6)	9 (22.0)
Month 1	54	16	17 (44.7)	4 (10.5)	4 (10.5)	13 (34.2)
Month 2	53	15	23 (60.5)	5 (13.2)	3 (7.9)	7 (18.4)
Month 4	41	4	19 (52.8)	4 (11.1)	1 (2.8)	12 (33.3)
Month 6	38	9	14 (48.3)	0 (0)	4 (13.8)	11 (37.9)

Table 4. Laboratory Values over Time

Visit	Baseline	Month 6	*P* Value
N	50	14	
WBC K/mcL	7.10 (0.32)	7.06 (0.54)	.94
RBC K/mcL	4.82 (0.07)	4.86 (0.09)	.62
HGB g/dL	13.56 (0.13)	13.97 (0.18)	.03
HCT %	40.13 (0.42)	41.39 (0.58)	.04
Platelets K/mcL	308 (9.3)	292 (11.6)	.09
HDL mg/dL	42.3 (1.6)	44.3 (2.6)	.34
LDL mg/dL	96.8 (3.0)	93.4 (3.7)	.46
Triglyceride mg/dL	99.0 (6.5)	85.4 (9.4)	.25
Total cholesterol mg/dL	160 (3.5)	152 (4.4)	.12

Note: HCT, hematocrit; HDL, high-density lipoprotein; HGB, hemoglobin; LDL, low-density lipoprotein; RBC, red blood cells; WBC, white blood cells.

percentage of calories of fat and protein in the diet increased, the total intake of fats and protein did no significantly change.

One would not expect eliminating carbohydrates to cause any difficulties or metabolic aberrations that would lead to laboratory abnormalities, and results from multiple studies of LCDs, including this study, seem to bear that out.[4-8] In fact, there is growing evidence that sucrose and high-fructose corn syrup can lead to dyslipidemia, hypertension, and nonalcoholic fatty liver disease because of the toxic end products of fructose metabolism.[17,18] By reducing carbohydrates in the diet, fructose in turn is decreased, which may be an added benefit of LCDs, leading to both weight loss and improvement in hepatic function.[19]

There are apparent limitations to this study. This study was intended to see if implementing an LCD in an office setting was practical and acceptable, and thus there was no control group. Although the diet was effective and acceptable in this setting, there is no way to know how a similar group would have done on a more traditional, fat-restrictive diet. Most of the study participants were girls, which may have skewed the outcome in either direction. Perhaps the most important shortcoming is that the intake and compliance was by self-report. In a follow-up analysis of their LCD study, Brehm and associates suggest their study participants may not be accurate in how they report their intake.[20] Finally, not all participants finished the study, and the results may reflect more motivated teens.

Still, in our study, the majority did lose weight and had improvement in their BMI. Most thought the diet was easier to follow than other diets, and two thirds felt the results were better than other diets they have tried. In our experience, the diet proved to be acceptable, and over a third believed they would remain on the diet beyond 1 year. Our study shows that the LCD is a safe, practical and effective intervention for obese teens in the pediatric office setting.

Acknowledgment

We gratefully acknowledge that this study was funded by a grant from the Dr. Robert C. and Veronica Atkins Foundation.

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