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The effects of a low-carbohydrate diet on appetite: A randomized controlled trial

T. Hu [a,*], L. Yao [b], K. Reynolds [c], T. Niu [d], S. Li [a], P. Whelton [a], J. He [a], L. Bazzano [a]

[a] *Department of Epidemiology, Tulane University School of Public Health and Tropical Medicine, 1440 Canal Street, SL-18, Suite 2000, New Orleans, LA 70112, USA*

[b] *Division of Epidemiology and Community Health, University of Minnesota, 1300 S 2nd St, Suite 300, Minneapolis, MN 55454, USA*

[c] *Department of Research & Evaluation, Kaiser Permanente Southern California, 100 South Los Robles, 2nd Floor, Pasadena, CA 91101, USA*

[d] *Department of Biostatistics and Bioinformatics, Tulane University School of Public Health and Tropical Medicine, 1440 Canal Street, SL-18, Suite 2001, New Orleans, LA 70112, USA*

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Abstract *Background and aims:* The relationship between dietary macronutrient composition and appetite is controversial. We examined the effects of a year-long low-carbohydrate diet compared to a low-fat diet on appetite-related hormones and self-reported change in appetite.

Methods and results: A total of 148 adults with a body mass index 30–45 kg/m^2, who were free of diabetes, cardiovascular disease and chronic kidney disease at baseline were randomly assigned to either a low-carbohydrate diet (carbohydrate [excluding dietary fiber]<40 g/day; N = 75) or a low-fat diet (<30% energy from fat, <7% from saturated fat; N = 73). Participants in both groups attended individual and group dietary counseling sessions where they were provided the same behavioral curriculum and advised to maintain baseline levels of physical activity. Appetite and appetite-related hormones were measured at 0, 3, 6 and 12 months of intervention. At 12 months, mean changes (95% CI) in peptide YY were −34.8 pg/mL (−41.0 to −28.6) and in the low-carbohydrate group and −44.2 pg/mL (−50.4 to −38.0) in the low-fat group (net change: 9.54 pg/mL [0.6 to 18.2]; p = 0.036). Approximately 99% of dietary effects on peptide YY are explained by differences in dietary macronutrient content. There was no difference in change in ghrelin or self-reported change in appetite between the groups.

Conclusions: A low-fat diet reduced peptide YY more than a low-carbohydrate diet. These findings suggest that satiety may be better preserved on a low-carbohydrate diet, as compared to a low fat diet.

Trial Registration: clinicaltrials.gov Identifier: NCT00609271.

* Corresponding author. Tulane University School of Public Health and Tropical Medicine, 1440 Canal Street, Suite 2000, New Orleans, LA 70112, USA. Tel.: +1 504 988 7323; fax: +1 504 988 1568.
E-mail address: thu1@tulane.edu (T. Hu).

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Introduction

Manipulations of the macronutrient contents of diet, in particular restriction of carbohydrate and fat, have been used extensively for weight loss and weight control in the past several decades. It is unclear whether reduction in body weight due to restrictions in either carbohydrate or fat results from changes in appetite or appetite-related hormones. Appetite is a complex phenomenon influenced by both behavioral and biological characteristics. A variety of peptides synthesized and released from the gastrointestinal tract are important regulators of appetite. For example, ghrelin is secreted from the stomach and functions as an appetite signal that increases hunger, stimulates food intake and decreases fat utilization in adipose tissue [1–3]. In contrast, peptide YY is released from the distal small intestine and colon after meals, and reduces appetite by increasing satiety [4,5]. Weight loss increases appetite stimulating hormones such as ghrelin and decreases satiety hormones such as PYY [6–8]. Measurement of these appetite-related hormones may provide novel and objective insights into the effects of dietary changes on biological markers of appetite [9].

Low-carbohydrate diets have been effective for weight loss and weight management [10–14]. Previous studies of low-carbohydrate diets provide some evidence that these diets may reduce appetite measured by self-report [15–19], while a few small studies ($N < 50$) have shown the opposite [20–22]. A recent meta-analysis on the topic concluded that ketogenic low-carbohydrate diets reduce appetite slightly from baseline measures, but comparison with a non-ketogenic diet as control group was not possible due to the small number of studies with such control groups which met inclusion criteria [23]. The mechanisms of potential reduction in appetite are unclear but may involve appetite-related hormones. To date, data on the effects of carbohydrate restriction on appetite-related hormones are scarce, limited to a few small, short-term studies [24,25]. The purpose of this study is to examine whether macronutrient composition of weight loss diets affects appetite and its regulation as reflected in levels of these appetite hormones, and to what degree these effects are independent of weight loss itself. Therefore, we examined the effects of a 12-month low-carbohydrate diet compared to a low-fat diet on both appetite-related hormones and self-reported change in appetite using data from a parallel, randomized, controlled trial among 148 obese adults.

Methods

Study participants

Obese adults were recruited by newspaper and television advertisements, mass mailings and e-mailings in the Greater New Orleans Area. Participants were eligible if they had a body mass index of 30–45 kg/m^2 and were 22–75 years of age. Individuals who were pregnant or who had type-2 diabetes, cardiovascular disease or chronic renal disease at baseline were not enrolled in the study. All procedures were approved by the Institutional Review Board of Tulane University Health Sciences Center and all participants provided written informed consent.

Study protocol

The study design has been described in detail elsewhere [26]. In brief, this trial was designed to examine the effects of a low-carbohydrate diet on body weight and cardiovascular risk factors. One hundred and forty-eight participants were randomly assigned to follow either a low-carbohydrate diet which restricted intake of digestible carbohydrate (total carbohydrate minus total fiber) to <40 g/day ($N = 75$), or a low-fat diet which restricted total and saturated fat intake to <30% and <7%of daily energy ($N = 73$), respectively [27,28]. Participants attended individual dietary counseling sessions weekly for the first month, followed by small group sessions every other week for 5 months, and monthly sessions for the remaining 6 months. During counseling sessions, participants met with a study dietitian, obtained optional recipes, and received supportive counseling. The same behavioral curriculum, including information on dietary fiber (recommended intake of 25 g/d) and types of dietary fats, was provided to both groups and was not altered over the course of the intervention. These common instructions emphasized the benefits of monounsaturated fats and recommend limiting or eliminating trans fats. Participants were advised to maintain their baseline levels of physical activity, which was assessed using validated measures at each follow-up visit.

A detailed medical history, and information on medication use and lifestyle risk factors was obtained at baseline by trained study personnel [26]. Body weight and other measures were obtained at baseline and each follow-up visit using standardized methods [26]. Two 24-h dietary recalls were obtained from each participant by a certified study dietitian at baseline and at each of follow-up examination. One recall was collected on a week day and the other on a weekend day. For the purposes of quality control, 5% of recalls were recorded for review. Dietary nutrient intakes were calculated using the food composition tables included in the Nutrition Data System for Research software [29].

Measurement of outcome variables

Blood samples were collected at baseline and during clinic visits at 3, 6 and 12 months of intervention. Appetite-related hormones, peptide YY and ghrelin, were measured in the Biomarker Core Laboratory of the Irving Institute for Clinical and Translational Research at Columbia University Medical Center. Peptide YY was measured using radioimmunoassay methods and commercially available reagents (Millipore, Billerica, MA).The inter-assay coefficients of variation was 7.1% for peptide YY. Ghrelin