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Association of decrease in carbohydrate intake with reduction in abdominal fat during 3-month moderate low-carbohydrate diet among non-obese Japanese patients with type 2 diabetes☆

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ABSTRACT

Objective. The effectiveness of a moderate low-carbohydrate diet (M-LCD) has been demonstrated in terms of glycemic control, body weight and serum lipid profiles. We investigated the effect of a 3-month M-LCD on visceral adipose tissue (VAT) and subcutaneous adipose tissue (SAT), and examined an association between decrease in carbohydrate intake and reduction in abdominal fat among patients with Type 2 diabetes mellitus (T2DM).

Methods. Seventy-six patients (45 men and 31 women; mean age ± SD: 59.5 ± 11.1 years) with T2DM were instructed to follow an M-LCD for 3 months. We assessed abdominal fat distribution using computed tomography and macronutrient intakes from 3-day dietary records at baseline and after 3 months.

Results. The patients complied well with the M-LCD – %carbohydrate: %fat: %protein at baseline and after 3 months were 51:27:15 and 41:33:18 in men and 54:27:16 and 42:37:19 in women, respectively. VAT and SAT significantly decreased during the 3 months (P for time <0.001 for both). Decrease in carbohydrate intake (g/day) and %carbohydrate were correlated with decrease (%) in VAT. The correlations were significant in men (Spearman correlation coefficient r = 0.469 for carbohydrate intake (g) and r = 0.402 for %carbohydrate) but not in women (r = 0.269 and 0.278, respectively). The correlations in men remained significant in multiple regression analysis adjusted for age and changes in energy intake.

Conclusions. In men, decrease in carbohydrate intake was significantly correlated with VAT loss during a 3-month M-LCD, independently of reduction in energy intake.

Abbreviations: VAT, visceral adipose tissue; SAT, subcutaneous adipose tissue; LCDs, low carbohydrate diets; T2DM, type 2 diabetes mellitus; CARD, carbohydrate-reduced diet; M-LCD, a moderate low carbohydrate diet; HbA1c, hemoglobin A1c; OGTT, oral glucose tolerance test; BW, body weight; BP, blood pressure; FBG, fasting blood glucose; IRI, fasting serum insulin; TG, triglyceride; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; TAT, total adipose tissue; WC, waist circumference; CT, computed tomography; BMI, body mass index; NGSP, National Glycohemoglobin Standardization Program; PFC, protein: fat: carbohydrate.

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1. Introduction

Abdominal fat accumulation, both of visceral adipose tissue (VAT) and subcutaneous adipose tissue (SAT), is known to be strongly linked to the development of metabolic diseases [1–6] even among non-obese individuals [7,8]. Various diet and/or exercise interventions, including low carbohydrate diets (LCDs) [9,10], have reduced an excess of abdominal fat [11–14] and have been studied in various branches of medicine. The effectiveness has been attributed to unique mechanisms, including control of appetite, hormones, nervous system, weight and blood lipids and glucose [15–18]. Given their beneficial effects in the control of blood glucose and other cardiovascular risk factors [19–21], they are suitable for patients with type 2 diabetes mellitus (T2DM) [22]. However, most large-scale and long-term cohort studies over the past 5 to 20 years have indicated that strict carbohydrate restriction in a diet rich in animal fat and protein increased mortality from cancer or cardiovascular disease [23,24]. Therefore, more attention has been paid to a moderate, non-ketogenic LCD with carbohydrate of about 30–45% of total energy as being safer compared with a strict LCD with carbohydrate of less than 26% of energy or 30 g/d [21]. We have already demonstrated the effectiveness of a new carbohydrate-reduced diet (CARD), a moderate LCD (M-LCD) with about 30–45% energy from carbohydrate, in Japanese patients with mild and even severe T2DM [25–27].

In this regard, we have reported that a 6-month M-LCD was effective as a dietary treatment for abdominal fat accumulation in patients with T2DM [27]. Specifically, in women, there was a preferential decrease in VAT and correlations were observed between changes in abdominal fat and those in cardiovascular disease factors. In this study, however, we did not assess a relationship between changes in macronutrient intakes and abdominal fat loss by following an M-LCD, nor exclude the influence of anti-diabetic drugs. Statistically, as it is considered that the influence of individual differences in background factors can be partly eliminated in the evaluation of associations between decrease in carbohydrate intake and abdominal fat, the effect of reducing carbohydrate can be demonstrated more clearly. Few studies have evaluated an association between changes in carbohydrate (% of total energy or g/day) and those in abdominal fat. In addition, abdominal fat may be reduced in a shorter period than six months considering the speed of decrease [28,29], so a study period of about 3 months may be more appropriate.

Therefore, the aim of this study was to investigate early effects of an M-LCD on VAT and SAT, and to examine associations of changes in macronutrient intakes, particularly reduction in carbohydrate intake, with those in abdominal fat among patients with T2DM who did not receive anti-diabetic drugs.

2. Subjects and methods

2.1. Study design

We recruited T2DM outpatients at the Haimoto Clinic from March 2010 to January 2012. Both newly and previously diagnosed patients were enrolled. We measured fasting blood glucose (FBG) and hemoglobin A1c (HbA1c) in all patients and the oral glucose tolerance test (OGTT) was conducted within a month whenever possible. To be eligible for the present study, patients had to meet at least one of following criteria [30]; 1) FBG ≥ 126 mg/dl, 2) 2-h plasma glucose value in the 75 g OGTT ≥ 200 mg/dl, and/or 3) HbA1c ≥ 6.5%. Exclusion criteria included serum creatinine levels >2.0 mg/dL, severe complications from diabetes (proliferative retinopathy, symptomatic neuropathy, or diabetic foot), ketoacidosis, soft drink ketosis, cancer, severe heart failure, and/or liver cirrhosis. Of 167 eligible patients, we excluded those taking anti-diabetic medicine during the study period (n = 33) because some anti-diabetic drugs affect body weight [31]. Also excluded were patients who were already following a CARD (n = 26) and those who reported a weight loss within a month (n = 2). Five patients did not agree to take part in this study. The final number of outpatients with T2DM enrolled was 101. All participants gave written informed consent and the study protocol was approved by the Ethics Committee of the Nagoya Tokushukai General Hospital (approval number 2010-2-104).

2.2. Anthropometry and blood chemistry

We measured the participants' body weight (BW), blood pressure (BP) and HbA1c levels every month. Levels of FBG and fasting serum insulin (IRI), triglyceride (TG), low-density lipoprotein cholesterol (LDL-C) and high-density lipoprotein cholesterol (HDL-C) were measured at baseline and after 3 months. The VAT, SAT, total adipose tissue (TAT) and waist circumference (WC) were also assessed at baseline and after 3 months, by computed tomography (CT).

BW was determined using an electronic scale while patients were wearing only underwear. Body mass index (BMI) was calculated by dividing weight in kilograms by the square of height in meters. The cross-sectional areas of VAT and SAT were measured by CT (X-ray CT system Pronto Si, Hitachi Medical Corporation, Tokyo), scanning patients at the navel level. These areas and WC were computed using image analysis software (Fat Pointer; version 1.10, Hitachi Medical Corporation, Tokyo) as described previously [1].

Plasma glucose concentrations were determined by the enzymatic method (Shino-Test Corporation, Sagamihara, Japan). Serum insulin levels were measured using the standard double antibody radioimmunoassay method (Fujirebio Inc., Tokyo). Enzymatic methods were used to measure TG levels (Daiichi Pure Chemicals Co., Tokyo). Direct methods were applied to assay serum LDL-C and HDL-C levels (Daiichi Pure Chemicals Co., Tokyo). HbA1c levels were measured using high-performance liquid chromatography (Arkley Inc., Kyoto) and indicated as National Glycohemoglobin Standardization Program (NGSP) values [32].

2.3. Carbohydrate-reduced diet (CARD)

The main principle of the CARD used in this study was to eliminate carbohydrate-rich foods in accordance with each patient's HbA1c level, as described previously [25–27]. In brief, patients with an HbA1c level < 9.0% were asked to eliminate carbohydrate-rich foods from their dinner whereas patients with an HbA1c level ≥ 9.0% were requested to eliminate