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Original Article

Comparison of dietary energy and macronutrient intake at different levels of glucose metabolism

Li-Jun Yan[1], Sheng Jiang[2], Shi-An Sun[3], Zi-Jing Xie[2]

Departments of [1]Endocrinology, [3]Outpatient, Xinjiang Autonomous Regional Corps Hospital of Chinese People's Armed Police Forces, Urumqi 830091, Xinjiang Uighur Autonomous Region, P. R. China; [2]Department of Endocrinology, First Affiliated Hospital to Xinjiang Medical University, Urumqi 830091, Xinjiang Uighur Autonomous Region, P. R. China

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Abstract: The aim of this study was to evaluate energy and glycolipid metabolism by determining the intake of energy and macronutrients in persons with differing glucose metabolisms. In total, 147 patients who were newly diagnosed with pre-diabetes, 177 patients with diabetes, 139 patients who were previously diagnosed with diabetes, and 140 patients with normal blood sugar were selected from the 103rd Regiment of Xinjiang. All patients had Han nationality and were over 30 years old. Their energy and macronutrient intakes were analyzed from data obtained from a 3-day food weighing household investigation. Compared to the normal group, the patients in the previously and newly diagnosed diabetic groups were older, less educated, and had a greater prevalence of hypertension ($P<0.05$). Compared to the normal group, patients with abnormal glucose metabolism had larger waist circumferences; higher systolic and diastolic blood pressure; higher postprandial glucose; higher total cholesterol; lower high-density lipoprotein cholesterol (HDL-C; $P<0.05$); higher intakes of energy, carbohydrates, and fat; and lower intakes of protein and fiber. In addition, the newly and previously diagnosed patients had higher fasting glucose levels ($P<0.05$). Compared to the normal group, patients with abnormal glucose metabolism in each sex subgroup also had larger waist circumferences, and more men had abdominal obesity ($P<0.05$). Diabetes or pre-diabetes patients had a higher intake of energy, carbohydrates, and fat, but a lower intake of proteins and fiber. They had severe abdominal obesity, a greater prevalence of hypertension, higher total cholesterol levels, lower HDL-C, and poor blood glucose and glycosylated hemoglobin levels, especially postprandial plasma glucose levels.

Keywords: Diabetes, prediabetes, energy intake, macronutrients, abdominal obesity

Introduction

The global incidence of diabetes has increased gradually in just a few decades, but it has shown a rapid growth in China [1, 2]. Considering the problem of a growing diabetic population, shortages of health professionals, and an underfinanced Chinese health care system, it is crucial to provide effective education programs for a growing number of people with diabetes or with a high risk of diabetes, particularly in poor and less educated rural communities. Part of the population with normal glucose metabolism, which has important features including insulin resistance, ectopic fat deposition, and abdominal obesity [3], might get diabetes (diabetes mellitus) via a pre-diabetic stage (prediabetes) [4]. Diabetes occurs when the function of insulin cannot be sufficiently compensated. In addition to genetic susceptibility factors, the impact of environmental factors, interactions between genes and the environment, and great changes in dietary patterns play a very important role. With increased industrialization and globalization, various processed and semi-processed foods are becoming exceedingly popular, and the total energy intake of humans has significantly increased [5]. Especially, the intake of carbohydrate as the chief energy supply is to be recommended, and can be seen from the food pyramid of the U.S. Department of Agriculture [6]. However, the proportion of carbohydrates in the Chinese diet is traditionally higher because of food habits [7], and may partially account for differences in the rates of diabetes onset in China and other countries.

Traditionally, it was believed that disordered dietary fat and energy metabolism was closely related to the incidence of cardiovascular disease, but recent studies have found that carbohydrate intake is also associated with a disordered metabolism of sugar and lipid in patients with cardiovascular risk factors [8]. Some studies suggested that the glucose load played an important role in the incidence of metabolic diseases including type 2 diabetes [9]. Recently, some studies investigated the impact of different diet programs on energy and glucose metabolism, including a low-fat diet, a low-carbohydrate diet, and a very low-carbohydrate ketogenic diet, which had different characteristics, but generally, a moderate caloric restriction. Researchers showed that a low glycemic load (GL) diet could reduce C-reactive protein levels and moderately increase adiponectin levels in overweight and obese adults [10]. Other researchers found that a low-glucose index diet could reduce the tumor necrosis factor α levels of monocytes in elderly and obese adults [11], which could help to improve their insulin resistance.

Systemic evaluation and analysis also showed that a low-carbohydrate diet could result in weight loss in patients with diabetes, and improve their levels of glycemic control and cardiovascular risk markers [12]; this diet had similar effects to a low-fat diet [13]. In addition, the Chinese Daqing study, the Finnish Diabetes Prevention Study, and the American Diabetes Prevention Program, all found that moderate weight loss through lifestyle interventions could significantly reduce the early development of diabetes in individuals with abnormal glucose tolerance [14-16], suggesting that the correction of the imbalance between energy intake and energy consumption was crucial for the regulation of metabolic disorders. However, there is still no unanimous conclusion about the appropriate amount of energy, and the relationship of various nutrients with an abnormal glucose metabolism. Recently, a few studies have analyzed the differences of dietary energy and macronutrient intakes in a population with different glucose metabolism levels using horizontal comparisons. In this study, the differences of dietary energy and macronutrient intakes, glycolipid metabolism, and the possible relationship with abdominal obesity were investigated in a Chinese population with different glucose metabolism levels, to aid the selection of appropriate diet programs for diabetes and pre-diabetes patients.

Material and methods

Subjects

Resident workers of the Xinjiang Production and Construction Corps 103 Mission were screened between October 2008 and May 2009. Patients with fasting blood glucose ≥6.1 mmol/L were identified using an Oral Glucose Tolerance Test (OGTT). The diagnoses of diabetes and pre-diabetes were based on the American Diabetes Association criteria 2003 [17]. In total, 147 patients who were newly diagnosed with pre-diabetes, 177 patients who were newly diagnosed with diabetes, 139 patients who were previously with diagnosed diabetes, and 140 patients with normal blood sugar, matched according to sex and age to the pre-diabetes cases, were selected. All the selected patients had Han nationality and were over 30 years old. This study was conducted in accordance with the Declaration of Helsinki and with approval from the Ethics Committee of the First Hospital Affiliated to the Xinjiang Medical University. Written informed consent was obtained from all participants. Retrospective dietary surveys and 3-day household food weighing investigations were performed between July and September 2009. The exclusion criteria were as follows: no chronic infections without effective treatment, no severe cardiac and cerebrovascular accidents with sequelae, no obvious liver dysfunction, no hyperthyroidism without treatment, and long-term use of diuretics and adrenal corticosteroids.

Demographic indicator collection

Data were collected through questionnaires. The survey items included age, sex, educational level (less than primary school, less than high school, or more than junior college), labor intensity (light, medium, or heavy), regular exercise status (moderate intensity movements were defined as exercise for more than 5 days a week with a total of 150 min or more), smoking status (at least one cigarette per day for 1 year), drinking status (at least once a week, a total of at least two units of alcohol for 1 year), and hypertension status (diagnostic criteria

Table 1. Demographic and medical history characteristics of groups with different glucose metabolism levels

Grouping		Already diagnosed DM	Newly diagnosed DM	Pre-DM	Normal
N		139	177	147	140
Age 1) $\bar{x}$±s		61.3±10.5[a]	56.0±12.6	53.6±12.9	54.1±12.8
Gender (Male/Female)		59/80	77/100	71/76	68/72
Educated levels *N (%)* 2)	Under the primary school	104 (74.8)	128 (72.3)	83 (56.5)	80 (57.1)
	Under the high school	18 (12.9)	27 (15.3)	30 (20.4)	29 (20.7)
	Above the junior college	17 (12.2)	22 (12.4)	34 (23.1)	31 (22.1)
Labour intensity *N (%)*	Light	46 (33.1)	49 (27.7)	65 (44.2)	52 (37.1)
	Medium	21 (15.1)	36 (20.3)	13 (8.8)	17 (12.1)
	Heavy	72 (51.8)	92 (52.0)	69 (46.9)	71 (50.7)
Regular exercises *N (%)*		65 (46.8)	75 (42.4)	52 (35.4)	52 (37.1)
History of smoking *N (%)*		50 (34.0)	68 (38.4)	39 (28.1)	46 (32.9)
History of drinking *N (%)*		120 (86.3)	164 (92.7)	137 (93.2)	130 (92.9)
Diagnosis of high blood pressure *N (%)* 3)		77 (55.4)	119 (67.2)	70 (47.6)	55 (39.3)

Note: 1) F=11.535, P=0.000; 2) *Chi-Square*=19.225, P=0.000; 3) *Pearson* χ^2=26.994, P=0.000; All other indicators were with $P>0.05$. a: The differences of the groups compared with other three groups had significance. b: There was no significant difference between the two groups.

were high blood pressure or prescription of antihypertensive drugs).

Anthropometric indicator collection

Height, body weight, waist circumferences (WC), and hip circumferences were measured. Body-mass indices and waist-to-hip ratios were calculated. Body mass index was calculated as kg/m^2. The horizontal circumference of the midpoint between the subcostal lowest point and the iliac crest was taken as the WC, while the horizontal circumference of the most prominent area of the gluteus maximus was taken as the hip circumference. The measuring scale was used with appropriate tightness.

Dietary survey

The survey was performed with a food frequency questionnaire and a 3-day household food weighing investigation. The local medical staff members were trained to provide assistance. Diabetic diet software was used (edited by Aihong Cao) to calculate the total daily intakes of energy, carbohydrates (CHO), fat, protein (PRO), and fiber.

Biochemical parameters

Blood samples were obtained during a fasting state (8-12 h) and serum was separated from cells after immediate centrifugation. Samples were placed in -20°C freezers within 2 h of collection until required for analysis. OGTTs were performed using 75 g anhydrous glucose, oral powder. Fasting plasma glucose (FPG), total cholesterol, triglycerides, and high-density lipoprotein cholesterol (HDL-C) were detected from overnight fasting venous blood. After immediate centrifugation, venous blood after oral glucose intake or 2 h postprandial blood was used to detect the 2 h glucose level using an OGTT (postprandial plasma glucose, PPG). Blood glucose was determined using the glucose oxidase method, and cholesterol and triglycerides were analyzed using the oxidase method. HDL-C was measured using the direct method. Ningbo Asia-Pacific reagents and the charm 1800 automatic biochemical analyzer were used. Low-density lipoprotein cholesterol was calculated using the Friedewald formula. Glycosylated hemoglobin (HbA1c) was measured using affinity chromatography.

Sample size calculation

The required sample size was calculated using a pretest. According to the result for dietary energy in a community, s=1806 kcal/d, δ=256 g/d, $t_{0.05}$=1.960, N=(1.960×1806)^2/256^2=98.

Statistical analysis

This was a cross-sectional study. The data were processed by two persons who were blinded to

Table 2. Anthropometric characteristics, biochemical parameters and dietary survey results of groups with different glucose metabolism levels ($\overline{x}\pm s$)

Indicators	Newly diagnosed diabetes	Already diagnosed diabetes	Pre-diabetes	Normal	*F*	*P*
WC (cm)	88.5±9.7	90.8±9.6	88.2±10.5	84.1±10.1[a]	11.158	0.000
WHR	0.91±0.07	0.92±0.07	0.91±0.08	0.88±0.08[a]	8.709	0.000
BMI (kg/m^2)	24.8±3.3	25.1±3.5	24.9±3.6	24.1±3.1	2.163	0.091
SBP (mmHg)	124.9±19.6	131.9±18.9[a]	123.9±18.9	121.4±14.9	8.425	0.000
DBP (mmHg)	80.3±12.1	78.7±11.4	79.2±12.0	76.3±10.5	3.169	0.024
FPG (mmol/l)	8.17±2.34	9.42±3.60	5.60±0.97[b]	5.33±0.32[b]	118.167	0.000
PPG (mmol/l)	12.53±6.88	15.99±6.63	8.32±1.93	6.97±0.79	95.750	0.000
HbA1c (%)	7.54±0.61	8.07±0.66	6.62±0.29	5.08±0.45[a]	49.83	0.000
TC (mmol/l)	5.61±1.48	5.60±1.40	5.78±1.57	3.97±0.82[a]	55.965	0.000
TG (mmol/l)	2.07±1.88	1.75±1.38	2.08±1.78	2.20±1.09	2.009	0.111
HDL-c (mmol/l)	1.46±0.56	1.42±0.46	1.49±0.48	2.99±0.84[a]	233.535	0.000
LDL-c (mmol/l)	3.24±1.14	3.45±1.16	3.43±1.30	3.14±1.02	2.339	0.072

Note: a: The differences of the groups compared with other three groups had significance. b: There was no significant difference between the two groups.

the data. Statistical analysis was performed using SPSS 16.0 software. Measurement data among groups were compared using the F test (including multiple comparisons among groups using the Student-Newman-Keuls method), enumeration data were compared using the χ^2 test, and ranked data were compared using the rank-sum test. $P<0.05$ was considered to have statistical significance.

Results

Basic characteristics of the study subjects

The differences of age, educational level, and history of hypertension within the four groups had statistical significance. The average age of patients in the previously diagnosed diabetes group was 7.7 years older than in the pre-diabetes group, and 7.2 years older than in the normal group ($P=0.000$). The proportion of subjects educated to less than primary school level in the diabetes group was 18.3% higher than in the pre-diabetes group, and 17.7% higher than in the normal group. And the proportion of people educated to a level above junior college in the diabetes group was 10.9% lower than in the pre-diabetes group, and 9.9% lower than in the normal group ($P=0.000$). The proportion of patients with high blood pressure in the newly diagnosed diabetes group was 19.6% higher than in the pre-diabetes group, and 27.9% higher than in the normal group ($P=0.000$). Differences in sex, labor intensity, regular exercise, smoking, and drinking history had no significance ($P>0.05$). In addition, there was a significant difference between the prevalence of hypertension in the previously diagnosed and newly diagnosed groups, and it was 11.2% higher in the latter than in the former (**Table 1**).

Anthropometric characteristics, biochemical parameters and dietary survey results

The differences in the WC, waist-to-hip ratios, systolic and diastolic blood pressure, FPG, PPG, total cholesterol, and HbA1c in the four groups were statistically significant ($P=0.000$, 0.000, 0.000, 0.024, 0.000, 0.000, 0.000, 0.000, respectively). These indicators in the newly and previously diagnosed diabetes groups, and the pre-diabetes group ranged from 4.1-6.7 cm, 0.03-0.04, 2.5-10.5 mmHg and 2.4-4.0 mmHg, 0.27-4.09 mmol/L, 1.35-9.02 mmol/L, 1.63-1.81 mmol/L and 1.54-2.99% higher than in the normal group, respectively, while the HDL-C levels in the aforementioned 3 groups were 1.50-1.57 mmol/L lower than in the normal group ($P=0.000$, 0.000; **Table 2**).

Although the differences in FPG, energy, CHO, fat, and PRO among the four groups showed statistical significance ($P=0.000$), the results of multiple comparisons showed that the difference in the FPG between the pre-diabetes group and the normal group had no statistical significance. The PPG and HbA1c of the pre-diabetes group were 1.35 mmol/L and 1.54%

Table 3. Dietary survey results of groups with different glucose metabolism levels ($\overline{x}$±s)

Indicators	Newly diagnosed diabetes	Already diagnosed diabetes	Pre-diabetes	Normal	*F*	*P*
Energy (kcal/d)	1744.4±529.1[b]	1792.8±567.0[b]	2067.7±594.8	1534.4±327.0	25.973	0.000
CHO (g/d) (Energy%)	226.3±90.5[b] (51.9%)	220.5±84.0[b] (49.2%)	283.5±106.4 (54.8%)	180.5±69.5 (47.1%)	32.782	0.000
Fat (g/d) (Energy%)	71.9±28.4 (37.1%)	80.5±33.2[b] (40.4%)	79.5±28.0[b] (34.6%)	63.5±11.4 (37.2%)	12.435	0.000
PRO (g/d) (Energy%)	48.0±20.1[b] (11.0%)	46.5±19.4[b] (10.4)	54.3±19.0 (10.5%)	60.3±18.6 (15.7%)	15.593	0.000
Fiber (g/d)	8.82±3.66	8.99±3.90	8.29±1.57	10.84±4.75[a]	13.251	0.000

Note: a: The differences of the groups compared with other three groups had significance. b: There was no significant difference between the two groups.

Table 4. Differences of waist circumferences (WC) ($\overline{x}$±s) and abdominal obesity *N (%)* in gender stratified groups with various glucose metabolism levels

Gender and groups	WC (cm) ($\overline{x}$±s)	*F*	*P*	Abdominal obesity *N (%)*	*Pearson* χ^2	*P*
Male *N*=275						
Pre-diabetes	89.6±11.1	6.279	0.000	38 (53.5)	19.554	0.000
Newly diagnosed diabetes	89.7±9.0			36 (46.8)		
Already diagnosed diabetes	92.6±10.9			41 (69.5)		
Normal	84.7±10.9[a]			21 (30.9)		
Female *N*=328						
Pre-diabetes	87.0±9.7	5.408	0.001	59 (77.6)	7.421	0.060
Newly diagnosed diabetes	87.5±10.2			79 (79.0)		
Already diagnosed diabetes	89.5±8.3			70 (87.5)		
Normal	83.4±9.4[a]			50 (69.4)		

a: The differences of the groups compared with other three groups had significance. b: There was no significant difference between the two groups.

higher than in the normal group, respectively, while the differences in the levels of energy, CHO, fat, and PRO between the newly diagnosed diabetes group and the previously diagnosed diabetes group were not statistically significant, and the energy, CHO, and fat of the newly diagnosed diabetes group and pre-diabetes group were 210 kcal/d and 533 kcal/d, 45.8 g/d and 103.0 g/d, and 8.4 g/d and 16.0 g/d higher than in the normal group, respectively. The levels of PRO and fiber in the aforementioned two groups were 12.3 g/d and 6.0 g/d, and 2.02 g/d and 2.55 g/d lower than in the normal group (**Table 3**).

Sex-stratified analysis

The differences in the WC of both the male and female subgroups of the four groups were statistically significant (*P*=0.000, 0.001). The WC in the male and female subgroups of the normal group were 4.9-7.9 cm and 3.6-6.1 cm lower than in the other 3 groups with abnormal glucose metabolism. Among the four groups, only the difference in the proportion of men with abdominal obesity had a statistical significance (*P*=0.000), and this proportion in the normal group was 15.9%-38.6% lower than in the other three groups with abnormal glucose metabolism (**Table 4**).

Discussion

The subjects in this study were staff of the Xinjiang Department of Production and Construction Corps with relatively fixed work and residences. Many of them were workers undertaking various degrees of manual labor; their exercise was more regular and they rarely ate out, so it was easy to achieve a high compliance rate for the survey.

The results of this study indicated that the probability of pre-diabetes developing into diabetes increased with age. It was found to be related to the declining insulin secretion of aged pancreatic islet B cells. Meanwhile, a low education level may lead to lack of knowledge of health care, poor economic conditions, high caloric intake of staple foods, less intake of fresh fruits and vegetables, and no attention to exercises, resulting in abdominal obesity and glycolipid disorders, and thereby causing diabetes. In addition, the proportion of subjects with both diabetes and hypertension was higher, and may be associated with different degrees of insulin resistance that can affect the blood pressure levels in diabetes.

The dietary surveys and biochemical data indicated that the different dietary intake levels for energy and macronutrients were closely related to glycolipid metabolism and blood pressure. This may be associated with hyperinsulinemia caused by increased dietary GL and decreased insulin sensitivity. Since the dietary intake of protein may promote the role of insulin, the deficiency of protein intake might also aggravate insulin resistance. These findings are consistent with some previous studies. One of these revealed that diets with a high proportion of carbohydrate could raise fasting insulin levels compared to lower-carbohydrate diets [18], while another observational study showed positive associations between GL and triglyceride concentrations, and inverse associations between GL and HDL-C concentrations [19]. Above all, chronic hyperinsulinemia plays a critical role in the development of insulin resistance, along with hypertension and dyslipidemia, especially in the setting of excess energy intake and obesity [20].

Abdominal obesity was a manifestation of insulin resistance, and WC could reflect abdominal obesity. The results of this study should be further analyzed. Abdominal obesity and energy metabolism imbalance in the abnormal glucose metabolism groups were even more serious, and this may be related to a decrease in insulin sensitivity, and fatty acid metabolism disorders caused by increased dietary lipid load.

Generally, we found that the quantity of dietary carbohydrate, fat, PRO, and fiber intakes were closely related to the glucose metabolism status and energy/lipid metabolism disorders. If long-term follow-ups or dietary intervention treatments were performed, it would help in revealing the appropriate energy ratio for dietary macronutrients and in providing a reference for the prevention and treatment of metabolic disorders; this would be the direction for future efforts.

The major limitation of the work is that we did not describe the composition of the macronutrients, such as the type of fat (saturated, monounsaturated, and polyunsaturated), carbohydrates (simple and complex), protein (from animal and plant), and fibers (soluble and insoluble); analyze their biological actions; and adjust for confounders such as micronutrient intake. We will improve the study design and methods in the future.

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Disclosure of conflict of interest

None.

Address correspondence to: Dr. Zi-Jing Xie, Department of Endocrinology, First Affiliated Hospital to Xinjiang Medical University, Urumqi 830091, Xinjiang Uighur Autonomous Region, China. Tel: +86-991-4362693; Fax: +86-991-4521760; E-mail: zijingxiecn@yeah.net

References

[1] Yang W, Lu J, Weng J, Jia W, Ji L, Xiao J, Shan Z, Liu J, Tian H, Ji Q, Zhu D, Ge J, Lin L, Chen L, Guo X, Zhao Z, Li Q, Zhou Z, Shan G and He J. Prevalence of diabetes among men and women in China. N Engl J Med 2010; 362: 1090-1101.

[2] Xu Y, Wang L, He J, Bi Y, Li M, Wang T, Wang L, Jiang Y, Dai M, Lu J, Xu M, Li Y, Hu N, Li J, Mi S, Chen CS, Li G, Mu Y, Zhao J, Kong L, Chen J, Lai S, Wang W, Zhao W and Ning G. 2010 China Noncommunicable Disease Surveillance Group Prevalence and control of diabetes in Chinese adults. JAMA 2013; 310: 948-959.

[3] Siren R, Eriksson JG and Vanhanen H. Waist circumference a good indicator of future risk for type 2 diabetes and cardiovascular disease. BMC Public Health 2012; 12: 631.

[4] Wang H, Shara NM, Calhoun D, Umans JG, Lee ET and Howard BV. Incidence rates and predictors of diabetes in those with prediabetes: the Strong Heart Study. Diabetes Metab Res Rev 2010; 26: 378-385.

[5] Kang HM and Kim DJ. Total energy intake may be more associated with glycemic control compared to each proportion of macronutrients in the Korean diabetic population. Diabetes Metab J 2012; 36: 300-306.

[6] United States of Department of Agriculture: My pyramid. [Accessed 2010 Jan 28]. http://www.mypyramid.gov.

[7] He Y, Ma G, Zhai F, Li Y, Hu Y, Feskens EJ and Yang X. Dietary patterns and glucose tolerance abnormalities in Chinese adults. Diabetes Care 2009; 32: 1972-1976.

[8] Jakobsen MU, Dethlefsen C, Joensen AM, Stegger J, Tjønneland A, Schmidt EB and Overvad K. Intake of carbohydrates compared with intake of saturated fatty acids and risk of myocardial infarction: importance of the glycemic index. Am J Clin Nutr 2010; 91: 1764-1768.

[9] Roberts CK and Liu S. Effects of glycemic load on metabolic health and type 2 diabetes mellitus. J Diabetes Sci Technol 2009; 3: 697-704.

[10] Neuhouser ML, Schwarz Y, Wang C, Breymeyer K, Coronado G, Wang CY, Noar K, Song X and Lampe JW. A Low-Glycemic Load Diet Reduces Serum C-Reactive Protein and Modestly Increases Adiponectin in Overweight and Obese Adults. J Nutr 2012; 142: 369-374.

[11] Kelly KR, Haus JM, Solomon TP, Patrick-Melin AJ, Cook M, Rocco M, Barkoukis H and Kirwan JP. A low-glycemic index diet and exercise intervention reduces TNF (alpha) in isolated mononuclear cells of older, obese adults. J Nutr 2011; 141: 1089-1094.

[12] Ajala O, English P and Pinkney J. Systematic review and meta-analysis of different dietary approaches to the management of type 2 diabetes. Am J Clin Nutr 2013; 97: 505-516.

[13] Iqbal N, Vetter ML, Moore RH, Chittams JL, Dalton-Bakes CV, Dowd M, Williams-Smith C, Cardillo S and Wadden TA. Effects of a low-intensity intervention that prescribed a low-carbohydrate vs. a low-fat diet in obese, diabetic participants. Obesity (Silver Spring) 2010; 18: 1733-1738.

[14] Li G, Hu Y and Pan X. Prevalence and incidence of NIDDM in Daqing City. Chin Med J (Engl) 1996; 109: 599-602.

[15] Tuomilehto J, Lindström J, Eriksson JG, Valle TT, Hämäläinen H, Ilanne-Parikka P, Keinänen-Kiukaanniemi S, Laakso M, Louheranta A, Rastas M, Salminen V and Uusitupa M. Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. N Engl J Med 2001; 344: 1343-1350.

[16] Knowler WC, Barrett-Connor E, Fowler SE, Hamman RF, Lachin JM, Walker EA and Nathan DM. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. N Engl J Med 2002; 346: 393-403.

[17] Genuth S, Alberti KG, Bennett P, Buse J, Defronzo R, Kahn R, Kitzmiller J, Knowler WC, Lebovitz H, Lernmark A, Nathan D, Palmer J, Rizza R, Saudek C, Shaw J, Steffes M, Stern M, Tuomilehto J and Zimmet P. Follow-up report on the Diagnosis of Diabetes Mellitus. Diabetes Care 2003; 26: 3160-3167.

[18] Noakes M, Foster PR, Keogh JB, James AP, Mamo JC and Clifton PM. Comparison of isocaloric very low carbohydrate/high saturated fat and high carbohydrate/low saturated fat diets on body composition and cardiovascular risk. Nutr Metab 2006; 3: 7.

[19] Liu S, Manson JE, Stampfer MJ, Holmes MD, Hu FB, Hankinson SE and Willett WC. Dietary glycemic load assessed by food-frequency questionnaire in relation to plasma high-density-lipoprotein cholesterol and fasting plasma triacylglycerols in postmenopausal women. Am J Clin Nutr 2001; 73: 560-566.

[20] Reaven GM. Pathophysiology of insulin resistance in human disease. Physiol Rev 1995; 75: 473-486.