Control of Blood Glucose in Type 2 Diabetes by Modification of Conventional Diet Composition

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Abstract In this study, 100 clinically diagnosed types 2 diabetic patients were selected for investigation. The objective of this study was to control of blood glucose level in type 2 diabetic patient by the modification of conventional diet composition. The patients were studied using a randomized 5 week crossover design with the conventional and modified conventional diet (test diet) respectively. The mean body weight, BMI, waist circumference and waist to hip ratio were 60.1 ± 2.21 kg, 24.1 ± 2.71 kg/meter², 36.2 ± 0.762 inch and 0.904 ± 0.029 respectively with the conventional diet, that decreased to 59.5 ± 2.20 kg (P<0.01), 23.9 ± 2.73 kg/ meter² (P<0.05), 33.7 ± 0.512 inch (P<0.05) and 0.897 ± 0.026 (P<0.05) respectively after intervention of the test diet. The mean systolic and diastolic blood pressure were 124 ± 11.4 and 82 ± 6.9 mmHg respectively and after 5 weeks of intervention of test diet both the blood pressure decreased significantly (P<0.05) to 112 ± 8.6 and 69 ± 6.9 mmHg respectively. The mean fasting and postprandial blood sugar were 10.4 ± 0.38 and 12 ± 0.53 mmol/l with the conventional diet whereas it decreased significantly (P <0.001) to 8.1 ± 0.75 and 9.8 ± 0.40 mmol/l respectively. Before starting the test diet, the mean HbA1C was 6.4 ± 0.13 % but 5 week of post feeding the HbA1C decreased to 5.8 ± 0.19 % (P<0.001). The mean ALT value was 47.5 ± 8.95 u/l and decreased significantly (P < 0.05) to 24.5 ± 4.19 u/l. During conventional diet, the mean AST and ALP level were 55.8 ± 25.18 and 93 ± 6.06 u/l respectively, after intervention it decreased to 42.8 ± 27.43 and 75 ± 10.85 u/l but not significantly (P = 0.759, P= 0.337).

Keywords: blood glucose, conventional diet, modification diet, type 2 diabetes

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1. Introduction

Type 2 diabetes is increasing rapidly in both developed and developing countries. Asia is the home to four of the world's five largest diabetic populations, e.g. India with 33, China with 23, Pakistan with 9 and Japan with 7 million cases [1]. The prevalence in Bangladesh was 8.4 million in 2011 and by the year 2030, this number will almost be doubled to 16.8 million [2]. Around 80% of individuals will have developed microvascular complications by the time they have had diabetes for 20 years [3]. Diabetic retinopathy may be the most common microvascular complication of diabetes. It is responsible for ~ 10,000 new cases of blindness every year in the United States alone [4]. Further the incidence of microalbuminuria was 2% per year in patients with type 2 diabetes, and the 10-year prevalence after diagnosis was 25% [5,6]. Type 2 diabetes typically occurs in the setting of the metabolic syndrome, which also includes abdominal obesity, hypertension, hyperlipidemia, and increased coagulability.

These other factors can also act to promote CVD. Even in this setting of multiple risk factors, type 2 diabetes acts as an independent risk factor for the development of ischemic disease, stroke, and death [7]. Among people with type 2 diabetes, women may be at higher risk for coronary heart disease than men. The presence of microvascular disease is also a predictor of coronary heart events [8].

An analysis of antidiabetic therapy and the risk of pancreatic cancer in a retrospective case-controlled study [9] showed that after adjusting for age, sex, race, smoking, alcohol consumption, BMI, family history of cancer, duration of diabetes, and the use of insulin, the OR of developing pancreatic cancer was 4.99 (95% CI 2.59–9.61, P < 0.001) in patients having had insulin therapy compared with patients who had never had insulin therapy.It has been observed that Low Biologically Available Glucose (LoBAG) diets (diets reduced in carbohydrate content and increased the protein content) dramatically reduced the plasma glucose concentration [10], because carbohydrate is largely responsible for increasing blood glucose concentration. The dietary protein increases insulin secretion and lowers blood

glucose. Fat does not significantly affect blood glucose, but can affect insulin secretion and modify the absorption of carbohydrates [11]. In addition, low carbohydrate diets (carbohydrate 20%, protein 30% and fat 50%) have been reported to lower postprandial glucose levels and HbA1c, directly and indirectly by way of weight loss and may have beneficial effects on CVD risk factors [12,13]. Dietary components, carbohydrate, protein, fat have the greater effect on blood glucose. A LoBAG diet ingested for 5 weeks dramatically reduced the circulating glucose concentration in people with untreated type 2 diabetes. It may be hypothesized that changes in conventional diet composition with various carbohydrate, protein and fat ratios, over an extended period of time can significantly lower the integrated blood glucose concentration. Thus it may be possible to improve blood glucose control in people with type 2 diabetes by relatively simple adjustments in diet. Accordingly, it can be assumed that changes in conventional diet composition may affect anthropometric as well as physiological parameters and thereby improves glycemic status in type 2 diabetic patients. The main objective of the present study is to develop a diet that does not require oral agents or insulin but still controls blood glucose in people with type 2 diabetes. Our overall goal is to enable the persons with type 2 diabetes to control their blood glucose by adjustment in the composition rather than the amount of food in their diet.

2. Materials and Methods

The study was conducted in a diabetic center of Khulna city, Bangladesh during the period of June, 2008 to August, 2014. It was a cross over designed study. The subjects were selected purposively. A total number of 100 type 2 diabetic patients were recruited in this study irrespective of race, religion and socioeconomic status. Purposes and method of the study were briefed to each individual and informed consent was taken from the study subjects. The study subjects were selected following stringent inclusion and exclusion criteria:

2.1. Inclusion Criteria

Subjects were both sexes i.e. male and female with duration of type 2 diabetes for at least 3 months. Their PPBS concentration would be less than 13.0 mmol/L. Adult subjects with the age range of 30 to 60 years. One category subject was included - patients taking oral hypoglycemic agents and regular exercise

2.2. Exclusion Criteria

Subjects with co-morbid diseases (Infection, Stroke,

Myocardial infarction, major surgery etc.), pregnant and lactating women, history of medication for co-morbid diseases, over aged (>60 years) and Insulin dependent subjects were excluded.

2.3. Collection of Study Subjects

Before the study, all subjects were interviewed to determine their physical activity profile, food habit and to explain the study process and commitment in detail. A predesigned record form was used to record the relevant clinical, medical and socio-economic data such as age, marital status, height, weight, drug history from the consenting subjects.

2.4. Dietary Plan

Fifteen (15) days before beginning the study, the participants completed a food frequency questionnaire and noted their daily dietary menu and quantity at breakfast, snacks, lunch, afternoon and dinner. Then the author calculated the nutrient content of those foods specially carbohydrate, protein, fat from the reference value of Indian Council of Medical and Research. Thereafter the author calculated the total energy values. This habitual diet is designated as conventional diet. This diet consisted of 55% carbohydrate, 15% protein and 30% fat of total energy. At that time, participant's glycemic status (FBS, PPBS, HbA1c), hepatic enzymes (AST, ALP, AST), estimation of bilirubin, anthropometric (Height, weight, body mass index, waist circumference, hip circumference, waist- hip circumference ratio) and physiological parameter (Blood pressure) were recorded. Then they were instructed to maintain their current food habit and daily activity level about five weeks. After five weeks, participant's similar parameters were recorded. But all of the parameters were overall same as before. For this reason, the conventional diet was designated as control diet. Food items or menu of every meal were recorded by using an electric digital weighing balance.

Based on the idea or principles of low carbohydrate diet or LoBAG diet from different scientific reviews (described in introduction), a new diet was designed in which increased the protein content of the diet from 15% in the control diet to 18%. The carbohydrate was decreased from 55% to 44%. The fat was increased from 30% to 38%. The total energy value of both diets was kept in isocaloric and this second diet considered as test diet. After a 7 days washout period, the participants were requested to intake the test diet about 5 weeks after intervention of test diet, again the participants' glycemic status, hepatic enzymes, anthropometric and physiological parameters were recorded to determine the effects of test diet.

Table 1. Energy proportion of different nutrientsin Conventional and Test diet diets

Nutrients and energy	Nutrient proportion in conventional/control diet	Nutrient proportion in test diet
Carbohydrate	55%	44%
Protein	15%	18%
Fat	30%	38%
Energy (kilocalories)	Equal in both diet	

In anthropometric parameters, weight in kg; waist circumference and hip circumference in inch were recorded. Waist hip ratio calculated of by, WHR = waist circumference (inch) / hipcircumference (inch). Body mass index (BMI) by imperial BMI formula of BMI = Weight (Kg) / Height (meter) x Height (meter). Physiological parameter i.e. blood pressure recorded in mmHg unit. Glucose was estimated by enzymatic GOD-PAP method by automated chemistry analyzer, Hitachi 912 (Japan) using reagents of Randox Laboratory Limited, UK (Cat. No. GL366). For HbA1c determination, the VARIANT II Hemoglobin A1c Program utilizes the principles of ion exchange high performance liquid chromatography (HPLC). ALT (Alanine amino transferase) was estimated by UV method using ALT kit of RANDOX. The AST (Aspertate amino transferase) and ALP (Alkaline phosphatase) was done the Dimension® clinical chemistry system. Determination of serum bilirubin was performed by Evelyn Malloy method [14].

2.5. Statistical Analysis

Data were expressed as mean ± SE and / or range were appropriate. Comparison between two groups was done using Student paired t-test. Statistical analyses were performed using Statistical Package for Social Science (SPSS) for windows verson 16.5 (SPSS Inc., Chicago, Illions, USA). A two-tailed p value of < 0.05 was considered statistically significant.

3. Results and Discussion

In this study, 100 clinically diagnosed moderate types 2 diabetic patients were selected for investigation. For this purpose, firstly prepared a test diet with the modification of conventional diet particularly in terms of nutrient proportion but having the same caloric values.Secondly, to examine the efficacy of this modified conventional diet (test diet) whether it affects anthropometric and physiological parameters when applied over an extended period of time. Finally, to examinethe efficacy of the above test diet on plasma glucose concentration as well as some hepatic parameters. The ratio of carbohydrate: protein: fat measured in the control diet was 55:15:30. But after modification of control diet, the test diet possessed a ratio of 44: 18:38 for carbohydrate: protein: fat respectively. The energy values were equal in both cases of control diet and modification diet (test diet). The mean body weight, BMI, waist circumference and waist to hip ratio were 60.1 ± 2.21 kg, 24.1 ± 2.71 kg/meter², 36.2± 0.762 inch and 0.904± 0.029 respectively with the conventional diet, that decreased to 59.5 ± 2.20 kg (P<0.01), 23.9 ± 2.73 kg/ meter² (P<0.05), 33.7 ± 0.512 inch (P<0.05) and0.897 ± 0.026 (P<0.05) respectively after intervention of the test diet.

The mean systolic and diastolic blood pressure were 124 ± 11.4 and 82 ± 6.9 mmHg respectively and after 5 week of intervention of the test diet both the blood pressure decreased significantly to 112 ± 8.6 and 69± 6.9 mmHg respectively (P<0.05).The mean fasting and postprandial blood sugar were10.4 ± 0.38 and 12 ± 0.53 mmol/l with the conventional diet whereas it decreased significantly to (P <0.001) to 8.1 ± 0.75 and 9.8 ± 0.40 mmol/l respectively. Before starting the test diet, the mean HbA1C was6.4 ± 0.13% but 5 week of post feeding the HbA1C decreased to 5.8 ± 0.19 % (P<0.001). The mean ALT value was 47.5 ± 8.95 u/l and decreased significantly (P < 0.05) to 24.5 ± 4.19 u/l. During conventional diet, the mean AST and ALP level were 55.8 ± 25.18 and 93 ± 6.06 u/l respectively, after intervention it decreased to 42.8 ± 27.43 and 75 ± 10.85 u/l but not significant (P = 0.759, P= 0.337).

Table 2. Effects of test diet on anthropometric measurement of diabetic patients

Anthropometric measurement	Control diet	Test diet	P-value
Body weight (Kg)	60.1 ± 2.21	59.5 ± 2.20	P < 0.01
Body mass index(BMI)	24.1 ± 2.71	23.9 ± 2.73	P < 0.05
Waist circumference (WC)	36.2 ± 0.762	33.7 ± 0.512	P < 0.05
Hip circumference (HC)	39 ± 0.577	38.9 ± 0.584	P < 0.21
Waist-hip ratio (WHR)	0.904 ± 0.029	0.897 ± 0.026	P < 0.05

All data are expressed as mean ± SE; BMI, WC, HC and WHR measured as inch.

Table 3. Effects of test diet on physiological parameters of diabetic patients

Physiologicalparameters	Control diet	Test diet	P-value
Systolic blood pressure (SBP)	124 ± 11.4	112 ± 8.6	P < 0.01
Diastolic blood pressure (DBP)	82 ± 6.9	69 ± 6.9	P < 0.01
Fasting blood sugar (FBS)	10.4 ± 0.38	8.1 ± 0.75	P < 0.01
Postprandial blood sugar (PBS)	12 ± 0.53	9.8 ± 0.40	P < 0.01
Glycated hemoglobin A1c (HbA1c)	6.4 ± 0.13	5.8 ± 0.19	P < 0.01
Alanine transaminase (ALT)	47.5 ± 8.59	24.5 ± 4.19	P < 0.05
Aspertate transaminase (AST)	47.5 ± 8.59	24.5 ± 4.19	P < 0.76
Alkaline phosphatase (ALP)	47.5 ± 8.59	24.5 ± 4.19	P < 0.34
Bilirubin (BILI)	0.25± 0.29	0.25 ± 0.06	-

All data are expressed as mean ± SE; SBP and DBP measured as mmHg; FBS and PBS measured as mmol/liter; HBA1C, ALT and AST measured as U/L; ALP and BILI measured as mg/dl.

Modified dietary treatment in this study achieved an improvement in glycemic control, anthropometric and physiological parameter as well as hepatic enzymes in patients with type 2 diabetes. The carbohydrate: protein: fat ratio of the conventional diet was 55: 15: 30. But for the study purpose, the carbohydrate: protein: fat ratio modified to 44: 18:38. Here, mainly reduced the carbohydrate content, (particularly, starchy foods). This reduced carbohydrate diet or diet that is low in carbohydrate refers to as low biologically available glucose (LoBAG) diet. In this regard, Gannon and Nuttall [11] formulated a modified diet that contained 20:30:50 of carbohydrate, protein and fat respectively. Gannon et al. [10] formulated another diet having 30:30:40 of carbohydrate, protein, fat respectively. All of these diets lowered plasma glucose concentration, resulted in a significant decrease in glycated hemoglobin as well as some anthropometric and physiological parameters [11,15,16].

In the present study, postprandial blood sugar concentration significantly decreased (P < 0.01) after the 5 weeks intervention of the test diet. The test diet not only reduced the post meal sugar concentration but also significantly reduced (P < 0.01) the overnight fasting sugar concentration. In addition, the percentage of glycated hemoglobin A1c (HbA1c) concentration at the end of the 5 week study period was considerably decreased from a mean of 6.4 to 5.8. These findings agree with the other several studies. Loosely restricted 45%-carbohydrate diet led to greater reduction in hemoglobin A1c (HbA1c) and they alsodemonstrated that good glycemic control achieved with a 30%-carbohydrate diet among outpatients with severe T2DM [17]. Gannon and Nuttall [11] reported in 8 diabetic men in a randomized 5-week cross over design with a 5-week wash out period, even larger beneficial effects on glycemic control (both fasting and postprandial) were observed with low carbohydrate intervention (carbohydrate 20%, protein 30% and fat 50%) compared to control diet (carbohydrate 55%, protein 15% and fat 30%). Another study showedcarbohydrate restriction resulted in significant decrease (8.1% to 7.3%, p < 0.05) in glycosylated hemoglobin (HbA1c) compared to a high carbohydrate control diet [18]. Gannon et al. [15] also reported the low carbohydrate diet had lower HbA1c, glucose levels and insulin levels compared to high carbohydrate group. The similar study [19] reported a decrease in mean fasting plasma glucose (FPG) levels in diabetic subjects with low carbohydrate diet compared to low fat diet group. LoCHO diets have been reported to lower postprandial glucose levels directly and indirectly by way of weight loss [12,13]. When the carbohydrate content was 40 %, only the postprandial excursions were decreased. The fasting glucose concentration remained unchanged [16].

In this study, a five weeks intervention of test diet, a significant decreased mean body weight was observed in type 2 diabetic subjects (P<0.01). This finding is consistent with the findings of others [20] who reported Carbohydrate-restricted diets are at least as effective for weight loss as low-fat diets. There have been also reported low-carbohydrate diets generally perform better than low-fat diets for weight loss in normal subjects, and patients with metabolic syndrome or diabetes [21,22,23,24]. The current study also shown that at the time of taking conventional or control diet the mean data of BMI, WC and WHR were significantly reduced (p < 0.05) at the ends of5weeks intervention of test diet. Moreover, the 5 weeks post feeding of test diet ,the hip circumference slightly decreased but this result was not statistically significant (p = 0.215). However these findings agree with those of findings [25], they found that weight loss of 1 kilogram has been reported to decrease mean arterial blood pressure by approximately 1 mm Hg. Low carbohydrate diets have been reported to lower blood pressure by causing weight loss and improving the insulin sensitivity. Boden et al. [26] also reported, a Low CHO diet (20% carbohydrates) was associated with a significant reduction in body weight and BMI.Again, some studies supported that BMI, WC, and WHR or WHtR were equally correlated with the prevalence of hypertension in both genders [27, 28]. A study showed that BMI, WC, WHR and waist-to-thigh ratio was equally good predictors for the risk of diabetes [29]. Okosun et al. [30] reported that a positive association between weight, BMI, waist, hip, and WHR and increased risk of high blood pressure.

Another major finding of this study was that the test diet has the ability to affect hepatic enzymes. Most importantly, the enzyme, serum glutamic pyruvic transaminase (SGPT) or alanine transaminase (ALT) significantly decreased (P <0.05) at the end of the 5 weeks on the test diet. The other enzymes, serum glutamic oxaloacetic transaminase (SGOT) or aspartate transeaminase (AST) and alkaline phosphatase (ALP) level were considerably decreased but they found no significant differences. The mean BILI level was 0.25 u/l at control diet but after test diet intervention, the value remains constant. These findings are comparable with those of previous studies, elevated liver enzymes even within their normal range correlate well with increasing hepatic fat and NAFLD [31] which is in turn related to visceral fat deposition and general body insulin resistance [32]. In both men and women, otherwise unexplained serum aminotransferase enzyme elevation was significantly associated with higher body mass index (BMI), waist circumference (WC), serum triglycerides, fasting insulin and lower high-density lipoprotein (HDL) cholesterol, in which insulin resistance plays a central role. Indeed, hepatic and peripheral insulin resistance of a degree similar to that observed in type 2 diabetes [33]. Sato et al. [34] investigated that Nondrinkers with the highest GGT or ALT had a high risk of type 2 diabetes. The ALT orAST are associated with an increased risk of type 2 diabetes [35,36]. Although this finding disagreed with other investigators [37] who reported in Pima Indians that high ALT, but neither AST nor GGT, predicted the development of type 2 diabetes. Moreover, Cho et al. [38] supported this finding and stated that increased activity of liver enzymes, notably ALT, was associated with a twofold increase in the risk of type 2 diabetes independently of conventional risk factors.

4. Conclusion

In conclusion, a test diet prepared by modification of nutrient proportion from the conventional diet could play a role in the management of plasma glucose in type 2

diabetic patients. The ameliorating effect of the test diet to type2 diabetes might be due to its capability to regulate hepatic enzymes. Despite evidence suggesting more weight loss with isocaloric low carbohydrate diets, the issue of metabolic inefficiency with low carbohydrate dietary interventions is controversial and still not universally accepted. However, further study could be continued to explore the absolute feasibility of the test diet as a substitute of the oral hypoglycemic agents or insulin.

Competing Interests

The authors declared no competing interest.

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