Original Article

Korean Diabetes J 2010;34:303-311
doi: 10.4093/kdj.2010.34.5.303
pISSN 1976-9180 · eISSN 2093-2650

KOREAN DIABETES JOURNAL

A Comparative Study of Diet in Good and Poor Glycemic Control Groups in Elderly Patients with Type 2 Diabetes Mellitus

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Background: Identification of dietary patterns is important for glycemic management in elderly patients with type 2 diabetes mellitus (T2DM).

Methods: Elderly T2DM patients (> 65 years of age, n = 48) were categorized based on their concentration of glycated hemoglobin (HbA_{1c}). Subjects with HbA_{1c} levels below 7% were placed in the good control (GC) group and those with HbA_{1c} levels equal to or above 8% were placed in the poor control (PC) group. Anthropometric data, blood parameters, and dietary intake records were compared between the groups. Statistical analysis included Student's t-test, chi-square test, and Pearson correlation coefficient test.

Results: Anthropometric data, including body mass index (24.7 ± 2.9 kg/m^2), did not differ between the GC and PC groups. Significant abnormalities in blood glucose levels (P < 0.01), lean body mass (P < 0.01), and plasma protein and albumin levels (P < 0.05, P < 0.01) were found in the PC group. In contrast to the GC group, the PC group depended on carbohydrate (P = 0.014) rather than protein (P = 0.013) or fat (P = 0.005) as a major source of energy, and had a lower index of nutritional quality for nutrients such as protein (P = 0.001), and all vitamins and minerals (P < 0.001, 0.01, or 0.05 for individual nutrients), except vitamin C, in their usual diet. Negative correlations between HbA_{1c} levels and protein (r = -0.338, P < 0.05) or fat (r = -0.385, P < 0.01) intakes were also found.

Conclusions: Healthcare professionals should encourage elderly diabetic patients to consume a balanced diet to maintain good glycemic control.

Keywords: Diabetic elders; Fat; HbA_{1c}; Micronutrients; Protein

INTRODUCTION

Diabetes is the highest ranked disease amongst the top twenty leading causes of national disease burden in Korea [1]. The prevalence of diabetes is dramatically increasing along with aging; it is 0.9% for those around 20 years of age and 18.1% for those over 65 years of age in Korea [2], which is similar to the 20% found in the US data [3]. The International Diabetes Federation (IDF) estimates that the current number of diabetic patients—200 million worldwide—will increase to 333 million by the year 2025 [4]. Type 2 diabetes mellitus (T2DM) accounts for approximately 90% to 95% of all diagnosed cases of diabetes in adults [4].

Recent evidence indicates that dietary factors strongly affect glycemic control in T2DM [5,6] patients. Studies of the relationship between diet and incidence of T2DM reveal that a Western

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Received: Feb. 2, 2010; Accepted: Jul. 23, 2010
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dietary pattern may be positively associated with insulin resistance and an increased incidence for disease [7-9]. However, a diet high in fiber or low in glycemic load may be associated with a reduced incidence of T2DM [5]. Results from population-based studies show that protein and carbohydrate intakes are not associated with blood glucose and insulin levels, irrespective of diabetes. Fat intake is shown to be inversely related to insulin and insulin sensitivity only in non-diabetic participants; however, adjusting for sex, age, and body mass index (BMI), fat intake has revealed no association with glycemic control indexes [9]. Thus, little consensus has been achieved to date in terms of the dietary risk factors involved in T2DM. Moreover, these studies did not focus on the elderly, even though elderly people have different eating patterns than their younger counterparts, including a higher frequency of consumption of ethnic foods, smaller portion sizes, and a more organized, traditional three meals a day [10,11]. These differences have important implications for both nutritional health and the appropriateness of using customary techniques to manage blood glucose levels in elderly diabetic patients. However, data on food intake or nutrient risks for glycemic control in geriatric patients with diabetes are sparse. Therefore, the present study aimed to compare the food and nutrition intakes of elderly Korean T2DM patients with glycemic control status.

METHODS

Elderly T2DM patients receiving treatment at the outpatient diabetes clinics at Kyung Hee University Medical Center in Seoul, Korea between July 2005 and October 2005 participated in this study. Eligibility criteria included a willingness to participate in the study protocol and the understanding and signing of an informed consent form, being diagnosed with T2DM at least three months prior to the beginning of the study, and being 65 years of age or older. The criteria used for the diagnosis of T2DM were established by the Korea Diabetes Association (KDA), which are similar to those of the American Diabetes Association (ADA). Exclusion criteria included the presence of any serious complicated diseases such as hepatic or renal disease, malignant disease, recent surgery, and eating or hearing disorders. Individuals with glycated hemoglobin (HbA_{1c}) levels between 7% and 8% were also excluded. Following the screening process, 48 subjects participated in the present study. The average participant age was 71 ± 6 years (range, 65 to 84 years).

The study was designed as a cross-sectional, randomized group comparison of dietary risks and clinical parameters between a good glycemic control (GC) group (n = 30) and a poor glycemic control (PC) group (n = 18). Good glycemic control was defined as HbA_{1c} levels below 7%; HbA_{1c} levels equal to or above 8% were considered impaired, or poor, glycemic control. Both parameters are modifications of the ADA definition. Elders with HbA_{1c} levels between 7% and 8% had already been excluded from the study. Subjects had been treated either with diet alone, or with diet in combination with a hypoglycemic agent (sulfonylureas or metformin) and/or insulin.

All clinical evaluations were performed by physicians from the Kyung Hee University Medical Center. BMI was calculated as weight in kilograms divided by the square of height in meters (Jenix; Dongshin Co., Seoul, Korea). Body fat percentage and lean body mass (LBM) were measured via bioimpedance with a body composition analyzer (Inbody 4.0; Biospace, Seoul, Korea).

An average blood pressure (BP) value was obtained through 2 measurements using an electronic blood pressure meter (FT500; Jawon, Kyungsan, Korea) following 10 minutes of rest. Fasting blood samples were obtained by venipuncture using a serum-separator tube (BD Vacutainer Systems, Franklin Lakes, NJ, USA) following a 12-hour overnight fast. Fasting blood sugar (FBS) concentrations were measured by the glucose oxidase method using a Vitros analyzer (Ortho Clinical Diagnostics, Rochester, NY, USA). Similarly, post-prandial blood glucose levels were measured 2 hours after a meal. HbA_{1c} concentrations were determined in a central biochemistry laboratory by a commercial enzyme immunoassay (primary calibration; DAKO, Ely, Cambrigeshire, UK). Serum albumin and total protein, total lipids, triglycerides (TG), and high density lipoprotein cholesterol (HDL-C) concentrations were determined enzymatically using a chemistry analyzer (Hitachi 747; Hitachi, Tokyo, Japan).

Typical dietary intake was analyzed using 3-day food records. Detailed written directions for food record administration using a semi-quantitative method were given in advance. Dietary data were rechecked and collected by a trained interviewer. Food intake information was disaggregated, converted, and averaged into daily nutrient intakes using a computer-aided nutrition analysis program (CAN pro, version 2.0, 2002) developed by the Korean Nutrition Society (KNS) [12]. The quantitative and qualitative assessments of the typical diet were compared to the Korean Recommended Dietary Allowance (KRDA) [12] and the index of nutritional quality (INQ), which is a ratio of the nutrient-to-calorie content of foods [13].

To analyze food group intake patterns, the authors grouped all food items into 5 groups: grains (G), meat (M), vegetables (V), dairy products (D) and fruits (F) using the Korean food composition tower [12], which is similar to the United States Department of Agriculture (USDA) food pyramid [14]. Consumption of a food group was dichotomized into any consumption = 1; no consumption = 0. For example, an all-group intake pattern would be represented as GMVDF = 11111; a grain-excluded pattern would be GMVDF = 01111. Food group consumption patterns were then ranked and their energy composition ratios were determined. The GC and PC group patterns were then compared. The minimum accepted amount of individual food consumption was 30 g of solid food (i.e., grains, meats, vegetables, fruits); 15 g of solid dairy foods (i.e., cheese); or 60 g of liquid foods, which is consistent with a study by Kant et al. [15]. All analyses were conducted using a SAS software package version 9.1 (SAS Inc., Cary, NC, USA). Continuous variables were presented as a mean and standard deviation. Categorical variables were presented as absolute and relative frequencies. The chi-square test was employed to examine the effects of dietary diversity on categorical variables; continuous variables were compared using the *t*-test. Pearson correlation coefficient tests were performed for HbA_{1c} levels and nutrients intakes were analyzed after adjusting for sex and age. Statistical significance was accepted to be $P < 0.05$. This study was approved by the Institutional Review Board (IRB) at Kyung-Hee University Medical Center (KMC-IRB 2005-12-Na).

RESULTS

General subject characteristics are listed in Table 1. The average participant age was 71.1 ± 5.0 years. There were no significant differences between the GC and PC groups in the distribution of gender, age, living situation, and employment status. However, the average duration of diabetes was approximately twice as long in the PC group as in the GC group ($P < 0.01$). The GC group subjects were diagnosed with T2DM approximately 8 years earlier, when they were in their early 60s; the PC group subjects were diagnosed approximately 16 years prior, when they were in their mid 50s (Table 1). Level of education was higher in the GC group than in the PC group ($P < 0.05$, data not shown). All PC group subjects were treated by more complex medications, such as hypoglycemic tablets and insulin, and only 7% of the GC group subjects were treated solely with diet and exercise (Table 1).

Table 1. Clinical characteristics of study subjects [16]

	GCG (*n* = 30)	PCG (*n* = 18)	*P* value
Mean age, yr	70.2 ± 4.4	71.9 ± 5.5	NS
Sex			NS
Male	13 (43)	5 (28)	
Female	17 (57)	13 (72)	
Duration of diabetes, yr	7.9 ± 6.8	15.7 ± 10.1	< 0.01
Treatments of diabetes			
Diet and exercise	2 (7)	0	
Oral agent	25 (83)	5 (28)	< 0.05
Insulin	3 (10)	13 (72)	

Values are presented as a number (%) or mean ± standard deviation (range). Statistical analysis is by student *t*-test (for continuous variables) or by chi-square test (for categorical variables). GCG, good glycemic control group; PCG, poor glycemic control group; NS, not significant.

The anthropometric and clinical characteristics of the subjects are shown in Table 2. The GC group was of greater height and LBM ($P < 0.05$) than the PC group. The subjects' average BMI was within the normal range (20 kg/m^2 ≤ BMI < 25 kg/m^2), although it tended towards the overweight end of the range. In particular, females in the PC group (25.8 ± 3.3 kg/m^2) were found to be obese according to the BMI cut-off value (≥ 25 kg/m^2) recommended by the Korean Society for the Study of Obesity (KSSO) [17] and the World Health Organization (WHO) [18]. However, body weight, BMI, fat composition, and waist to hip ratio did not differ significantly between the GC and PC groups.

Mean glycated hemoglobin was 5.7 ± 0.6% in the GC group, whereas it was 9.8 ± 1.6% in the PC group. FBS levels in the PC group were 1.3 times higher in males and 1.4 times higher in females. In addition, 2-hour post-prandial blood sugar concentrations increased 1.7 fold in males and 1.3 fold in females compared to those of the GC group ($P < 0.05$). Male subjects in the PC group had the lowest serum albumin and protein concentrations among the study subjects ($P < 0.05$). Serum lipid profiles did not differ significantly according to glycemic control.

Table 3 presents daily average intakes for total calories and individual nutrients in the elderly diabetic patients. All subjects consumed fewer calories than recommended by the KRDA: 2,000 kcal in men and 1,700 kcal in women. There was no significant difference in total caloric intake between the GC

Table 2. Clinical measurements of T2DM elders with good glycemic control or poor glycemic

	Male		Female	
	GCG (n = 13)	PCG (n = 5)	GCG (n =17)	PCG (n = 13)
Height, cm	166.8 ± 4.7	160.2 ± 3.0[a]	154.4 ± 5.6	147.7 ± 5.0[b]
Weight, kg	67.2 ± 5.3	61.2 ± 5.7	59.0 ± 8.1	56.1 ± 6.0
Body mass index, kg/m^2	24.2 ± 2.4	23.9 ± 2.2	24.8 ± 3.7	25.8 ± 3.3
Waist to hip ratio	0.9 ± 0.0	0.9 ± 0.0	0.9 ± 0.1	0.9 ± 0.1
Body fat, %	22.4 ± 4.5	25.1 ± 5.0	31.7 ± 6.6	34.6 ± 7.2
Lean body mass, kg	51.9 ± 3.0	45.8 ± 4.5[a]	39.5 ± 4.1	36.4 ± 3.1[a]
SBP, mm Hg	124.5 ± 11.7	111.8 ± 11.6	124.6 ± 16.1	129.1 ± 16.3
DBP, mm Hg	69.5 ± 7.4	66.8 ± 8.3	70.8 ± 10.0	75.2 ± 13.8
FBS, mg/dL	108.7 ± 17.3	135.4 ± 33.4[a]	121.4 ± 32.2	164.9 ± 44.7[b]
PP2hr, mg/dL	162.0 ± 61.6	271.4 ± 64.6[b]	170.5 ± 46.2	223.3 ± 99.9
HbA_{1c}, %	5.7 ± 0.6	9.8 ± 1.6[b]	6.1 ± 0.6	9.0 ± 0.7[b]
Serum albumin, g/dL	4.8 ± 0.1	4.3 ± 0.1[b]	4.6 ± 0.2	4.5 ± 0.3
Plasma total protein, g/dL	7.4 ± 0.4	6.8 ± 0.3[a]	7.4 ± 0.4	7.5 ± 0.3
Hb, g/dL	14.3 ± 0.7	13.7 ± 1.7	12.9 ± 1.0	12.9 ± 1.3
TLC, cell/mm^3	1,893.5 ± 472.1	1,880.7 ± 616.7	2,286 ± 773.2	2,532.2 ± 404.0
Triglyceride, mg/dL	119.8 ± 68.5	128.0 ± 51.1	169.8 ± 83.6	151.5 ± 100.3
Total cholesterol, mg/dL	176.8 ± 24.0	170.8 ± 27.0	191.1 ± 31.2	199.8 ± 48.0
LDL-C, mg/dL	109.1 ± 21.7	109.6 ± 21.7	114.2 ± 29.3	126.0 ± 39.6
HDL-C, mg/dL	43.8 ± 11.0	35.6 ± 3.6	42.9 ± 11.2	45.8 ± 10.7

Values are presented as mean ± standard deviation. Differences between the GCG and PCG for the same gender at [a]$P < 0.05$, [b]$P < 0.01$ are by Student's t-test.
T2DM, type 2 diabetes mellitus; GCG, good glycemic control group; PCG, poor glycemic control group; SBP, systolic blood pressure; DBP, diastolic blood pressure; FBS, fasting blood sugar; PP2hr, postprandial 2-hour; HbA_{1c}, glycated hemoglobin; Hb, hemoglobin; TLC, total lymphocyte count; LDL-C, low density lipoprotein cholesterol; HDL-C, high density lipoprotein cholesterol.

and PC groups; however, energy sources differed significantly between the groups ($P < 0.001$, Table 3). Among male patients in the GC group, zinc was the only deficient nutrient among 19 nutrients, based on the KRDA [12], while deficiencies in vitamins A, E, B_2, calcium, and zinc were observed in the PC group. Protein ($P < 0.05$), fat ($P < 0.05$), zinc ($P < 0.05$) and vitamin E ($P < 0.05$) intakes were significantly higher in the GC group than in the PC group (Table 3). Among the female patients, vitamins A, E, B_2, calcium, and zinc were the nutrients lacking in the GC group, whereas all nutrients, with the exception of vitamin B_6, C, and phosphorus, were deficient in the PC group (Table 3). There were no significant differences in nutrient intakes between elderly women in the GC and PC groups.

Table 4 shows a qualitative assessment of a typical diet of diabetic elders. In male GC group elders, the INQ for all 13 nutrients was over 1. In female GC group elders, vitamins A, E, B_2, calcium and zinc were below 1. The overall diet quality of the GC group was significantly higher than that of the PC group. In the male PC group elders, the INQ for vitamins A, E, B_2, folate, calcium, and zinc were below 1. In the female PC group diabetic elders, all nutrients except vitamin B_6 and phosphorus were below 1. The GC group had a greater variety of nutrients in their diet than did the PC group, as shown in Table 5 ($P < 0.05$). Table 6 shows that the dietary diversity score was significantly higher in the GC group than in the PC group at every meal ($P < 0.05$), and especially at dinner ($P < 0.001$).

DISCUSSION

This study was performed to compare dietary intake quantity and quality between a GC group and PC group of Korean elderly patients with T2DM.

We observed that diabetic patients were more likely to be obese, have similar total- and low density lipoprotein-cholester-

Table 3. Comparison of average daily nutrient intakes in T2DM elders according to glycemic control

Nutrients	Male		Female	
	GCG (n = 13)	PCG (n = 5)	GCG (n = 17)	PCG (n = 13)
Calories, kcal	1,877.5 ± 254.4	1,697.9 ± 188.9	1,443.0 ± 320.6	1,435.7 ± 269.6
Carbohydrate, g	272.6 ± 48.1	296.4 ± 25.2	232.3 ± 48.0	256.4 ± 50.0
Protein, g	93.4 ± 20.9	69.9 ± 21.1[a]	64.7 ± 20.3	51.9 ± 16.4
Fat, g	49.7 ± 14.6	29.6 ± 11.3[a]	31.8 ± 13.8	23.2 ± 12.4
C:P:F ratio, %	58:20:24	70[a]:16:16[a]	65:18:20	71:15[a]:15[a]
Cholesterol, mg	216.4 ± 141.6	220.0 ± 108.5	179.2 ± 120.1	96.6 ± 99.3
Dietary fiber, g	9.2 ± 3.4	8.1 ± 0.7	8.4 ± 3.1	6.5 ± 1.8
Vitamin A, μg R.E	1,575.7 ± 857.8	844.0 ± 455.7[a]	1,323.9 ± 1,071.3	933.2 ± 567.7
Vitamin E, mg	12.9 ± 5.9	6.5 ± 3.7[a]	10.9 ± 5.5	8.8 ± 5.1
Vitamin B_1, mg	1.3 ± 0.3	1.2 ± 0.4	1.1 ± 0.4	0.8 ± 0.2
Vitamin B_2, mg	1.3 ± 0.4	0.9 ± 0.4	1.1 ± 0.4	0.8 ± 0.3
Vitamin B_6, mg	2.4 ± 0.7	1.9 ± 0.5	2.0 ± 0.7	1.6 ± 0.4
Niacin, mg	17.1 ± 4.3	13.2 ± 3.0[a]	14.6 ± 4.8	10.9 ± 3.9
Vitamin C, mg	105.4 ± 37.0	79.8 ± 30.6.	93.5 ± 51.4	75.7 ± 35.6
Folate, μg	317.6 ± 102.4	255.8 ± 96.9	278.5 ± 102.8	237.1 ± 77.1
Calcium, mg	761.1 ± 269.4	552.7 ± 290.7	659.5 ± 266.7	481.9 ± 186.2
Phosphorus, mg	1,336.5 ± 305.5	1,057.5 ± 380.8	1,117.6 ± 373.0	791.8 ± 202.4
Sodium, mg	4,759.1 ± 986.2	4,163.9 ± 1,055.3	4,065.4 ± 1,420.9	3,617.4 ± 518.7
Potassium, mg	3,557.4 ± 773.8	2,960.4 ± 896.3	3,020.3 ± 1,025.2	2,402.3 ± 597.3
Iron, mg	18.3 ± 5.8	14.2 ± 2.9	16.6 ± 6.1	11.9 ± 2.7
Zinc, mg	10.7 ± 2.4	8.1 ± 1.9[a]	9.3 ± 3.4	6.9 ± 1.8

Values are presented as mean ± standard deviation. Differences between the GCG and PCG for the same gender at [a]P < 0.05 are by Student's t-test.
T2DM, type 2 diabetes mellitus; GCG, good glycemic control group; PCG, poor glycemic control group.

ol, lower HDL-C, higher TG levels, and higher blood pressure than non-diabetic patients [9]. All female subjects with poor glycemic control, but not the male subjects with poor glycemic control, were classified as overweight based on a BMI ≥ 25 kg/m^2. This result is comparable to the Korean National Health and Nutrition Survey [12], where the proportion of overweight (BMI ≥ 25 kg/m^2) elders (≥ 65 years) was 11.2% (male) and 33.3% (female). There was no significant difference in the plasma lipid profiles and BP between the GC and PC groups; both groups were maintained within the normal range, which may have been due to medications for preventing vascular disease complications.

Medical nutrition therapy (MNT) is important in preventing diabetes, managing existing diabetes, and preventing or delaying the rate of development of diabetes complications. One goal of MNT that applies to individuals with diabetes is to achieve and maintain blood glucose levels in the normal range or as close to normal as is safely possible [19]. Tight glycemic control may help decrease or prevent other complications, such as myocardial infarction and hypertension, in diabetic populations [20].

The proportions of macronutrients in elderly diabetic patients diet differed significantly between the GCG (C:P:F = 62:19:22) and PCG (C:P:F = 71:15:15). Interestingly, the macronutrient composition in the GC group was similar to the recommended KDA ratio (C:P:F = 60:20:20).

Lower intakes of protein (r = -0.338, P < 0.05) or fat (r = -0.385, P < 0.01) were related to higher HbA_{1c} levels, while there was no association between carbohydrate intake and HbA_{1c} levels observed in the present study (data not shown). It is difficult to compare our results with those of other studies because so little research has explored the association between macronutrient intake and HbA_{1c} levels in Korean elders with T2DM. In addition, the effects of dietary macronutrient composition on metabolic profiles in patients with T2DM have been inconsistent [21].

In a meta-analysis of 13 trials on restricted carbohydrate diets in subjects with T2DM, levels of HbA_{1c}, fasting serum glucose, and triglycerides improved with lower carbohydrate diets [22]. A 10% increase in caloric intake from carbohydrates was associated with a 3.2 ± 1.2% increase in glucose levels (P = 0.047) and a 7.6 ± 0.6% increase in triglyceride levels (P = 0.001) [23]. Low-carbohydrate diets (< 45% of energy) resulted in good glycemic control within 6 months when substituted for a conventional low-fat diet in T2DM patients [22]. In another metabolic ward study involving seven T2DM patients, a maximal eucaloric (3,500 kcal weight maintenance diet) variation in carbohydrate to fat ratio (from 89% carbohydrate, 11% protein, 0% fat to 0% carbohydrate, 11% protein, 89% fat) modulated plasma glucose concentrations exclusively by decreasing basal hepatic glucose production and increasing insulin-stimulated non-oxidative glucose disposal [24]. However, in middle-age to elderly American Indians with diabetes, a higher consumption of total fat (> 25-30% of energy), saturated fatty acids (> 13% of energy), and monounsaturated fatty acids (> 10% of energy), and a lower consumption of carbohydrates (< 35-40% of energy) were associated with poor glycemic control in men, but not in women [25]. It is recommended that diabetic persons should derive ≥ 55% of their energy from carbohydrates, according to a meta-analysis of the literature [26]. Macronutrient intakes were not associated with blood glucose levels, insulin, or insulin sensitivity, irrespective of diabetes in the ATTICA study, a health and nutrition survey carried out in the province of Attica in Greece [9]. Meanwhile, American Diabetic Association guidelines continue to recommend relatively high total carbohydrate intakes (45-60% of energy) and reduced total and saturated fat intakes, as a weight

Table 4. Comparison of the index of nutritional quality in the diets of T2DM elders with good glycemic control or poor glycemic control

	GCG (n = 30)	PCG (n = 18)	P value
Protein	1.3 ± 0.4	0.9 ± 0.2	0.001
Vitamin A	1.0 ± 0.6	0.6 ± 0.4	0.014
Vitamin E	1.1 ± 0.5	0.7 ± 0.5	0.043
Vitamin C	1.3 ± 0.7	1.0 ± 0.4	0.056
Vitamin B_1	1.1 ± 0.3	0.9 ± 0.3	0.017
Vitamin B_2	1.0 ± 0.3	0.9 ± 0.3	0.001
Niacin	1.1 ± 0.4	0.8 ± 0.2	0.002
Vitamin B_6	1.4 ± 0.5	1.1 ± 0.3	0.009
Folate	1.1 ± 0.5	0.9 ± 0.3	0.025
Calcium	0.9 ± 0.4	0.6 ± 0.2	0.004
Phosphorus	1.5 ± 0.5	1.1 ± 0.3	0.002
Iron	1.3 ± 0.6	0.9 ± 0.2	0.006
Zinc	0.8 ± 0.2	0.6 ± 0.1	0.001

Values are presented as mean ± standard deviation. Differences between the GCG and PCG for the same gender are by Student's t-test. Index of nutritional quality is a ratio of the nutrient-to-calorie content of foods based on the Korean recommended dietary allowances. T2DM, type 2 diabetes mellitus; GCG, good glycemic control group; PCG, poor glycemic control group.

Table 5. Comparison of daily food group consumption patterns in T2DM elders with good glycemic control or poor glycemic control

GCG (n = 30)										PCG (n = 18)									
Rank	G	M	V	D	F	No. (%)	C:	P:	F	Rank	G	M	V	D	F	No. (%)	C:	P:	F
1	1	1	1	1	1	14 (47)	67	21	12	1	1	1	1	0	1	5 (28)	74	18	8
2	1	1	1	0	1	9 (30)	70	20	10	2	1	1	1	0	0	4 (22)	78	17	5
3	1	1	1	1	0	3 (10)	73	19	8	3	1	0	1	0	1	3 (18)	81	12	7
3	1	1	1	0	0	3 (10)	66	24	10	4	1	1	1	1	0	2 (11)	70	19	11
5	1	0	1	1	0	1 (3)	82	13	5	4	1	0	1	0	0	2 (11)	80	15	5
										6	1	1	1	1	1	1 (5)	72	17	11
										6	1	0	1	1	0	1 (5)	82	16	2

GMVDF means grain, meat, vegetables, dairy and fruit; 1 = food group present; 0 = food group absent. For example, GMVDF = 11111 denotes that all food groups were consumed.
T2DM, type 2 diabetes mellitus; C:P:F means carbohydrate:Protein:Fat; GCG, good glycemic control group; PCG, poor glycemic control group.

Table 6. Comparison of dietary diversity in T2DM elders with good glycemic control or poor glycemic control

Dietary diversity score	Breakfast		Lunch		Dinner	
	GCG	PCG	GCG	PCG	GCG	PCG
< 1	0	0	0	0	0	0
2	3 (10)	6 (34)	2 (7)	7 (39)	1 (3)	10 (55)
3	10 (33)	10 (55)	14 (47)	9 (50)	12 (40)	7 (39)
4	11 (37)	2 (11)	9 (30)	2 (11)	15 (50)	1 (6)
5	6 (20)	0	5 (16)	0	2 (7)	0
Mean ± SD	3.7 ± 0.9	2.8 ± 0.6	3.6 ± 0.9	2.7 ± 0.7	3.6 ± 0.7	2.5 ± 0.6
χ^2 value	10.9[a]		11.0[a]		21.2[b]	

Dietary diversity score values are mean ± standard deviation (SD). Differences between the GCG and PCG at [a]$P < 0.05$, [b]$P < 0.001$ are by chi-square test.
T2DM, type 2 diabetes mellitus; GCG, good glycemic control group; PCG, poor glycemic control group.

loss strategy for obese and overweight T2DM patients [27]. This study demonstrated that the GC group has more variety in their diet than the PC group ($P < 0.05$). A clear difference was observed in food group consumption between the GC and PC groups (Table 5). Among the GC group, half of the subjects consumed all 5 food groups, whereas, in the PC group, only 5% of subjects consumed all 5 food groups. Grains, meats, and vegetables were the most frequently consumed food groups; dairy products and fruits were the least consumed food groups among the study population (Table 5). Specifically, the dairy group was consumed in below-recommended quantities by all diabetic elders, which might be associated with the lower than recommended calcium and riboflavin intakes in this study.

The significantly higher dietary diversity scores in the GC group indicate that balanced food consumption is very important for glycemic control in elderly diabetics (Table 6). In the current study, this appears to be especially true at dinner. A greater variety of foods can provide a wider range of micronutrients and phytochemicals that may contribute to glycemic control in diabetes. Furthermore, lower intakes of vitamin E ($r = -0.296$, $P < 0.05$), B_1 ($r = -0.340$, $P < 0.05$), potassium ($r = -0.300$, $P < 0.05$) and zinc ($r = -0.286$, $P < 0.05$) appear to be correlated to higher levels of HbA_{1c} in the present subjects (data not shown). Recently, it was suggested that patients with T2DM have an altered metabolism of copper, zinc, and magnesium, which may be related to increased glycated hemoglobin values. The decreased levels of zinc ($P < 0.01$) and magnesium ($P < 0.0001$) were found in patients with T2DM when compared with controls. HbA_{1c} levels were positively correlated with levels of copper ($r = 0.709$, $P < 0.001$) and the copper/zinc ratio ($r = 0.777$, $P < 0.001$), and inversely correlated with zinc levels ($r = -0.684$, $P < 0.001$) [28].

Elderly Koreans are typically accustomed to more traditional Korean dietary patterns, which focus on steamed rice, vegetables, and kimchi, rather than greasy meats, oils, or dairy foods. Therefore, elderly diabetic Koreans may need encouragement to make more balanced food choices to boost their protein and fat consumption as part of this new nutritional approach.

In the present study, elderly patients who had higher HbA_{1c} concentrations (≥ 8%) also had longer duration of diabetes with middle-age onset and more complicated treatment (hypoglycemic agents and insulin) than elders whose HbA_{1c} concentrations were better controlled (< 7%) (Table 1). Similarly, data from the National Health and Nutrition Examination Survey (NHANES) noted that individuals with middle-age onset diabetes had substantially worse glycemic control compared with those with elderly-onset (41.6%). Individuals with elderly-onset diabetes were less likely to be taking glucose-lowering medications [3]. It appears that either the onset of diabetes or the duration of diabetes could be an important factor for determining treatment methods.

Many studies have demonstrated positive associations between academic background and nutritional knowledge, as well as glycemic control [29-31]. Elderly diabetic patients who had achieved a higher level of education had good glycemic control in the present study. In a previous study, Taiwanese elderly men with a higher education level had better nutritional knowledge and held more positive attitudes towards nutrition; they showed high fat or high cholesterol food restriction behaviors, paid attention to nutritional information, and ate regular meals [29]. Although the associations between nutritional knowledge and glycemic control were not analyzed in this study, it is speculated that information accessibility is a contributing factor to glycemic control in diabetic elders.

This study has the limitations of using a cross-sectional sample population from one hospital. However, the strength of the present study is in its collection of recent data, allowing for the assessment of dietary risks in elderly T2DM patients within a narrow age range (65 to 84 years). Clinical trials focusing on whether modifications to macronutrient composition improve glycemic control in elders with diabetes are needed.

We examined usual dietary patterns and levels of glycated hemoglobin in Korean elderly T2DM patients. We found that elderly men with poor glycemic control had higher carbohydrate and lower fat intakes compared to men with good glycemic control ($P < 0.05$). Elderly women with poor glycemic control had lower protein and fat intakes compared to women with good glycemic control ($P < 0.05$). Dietary patterns of the well-controlled group showed a similar distribution of macronutrients to the recommendations of the KRDA. A limited variety in food choices and lower micronutrient consumption were found in elderly patients with poor glycemic control, which could be related to their higher HbA_{1c} levels. Lower intakes of protein ($r = -0.338$, $P < 0.05$) and fat ($r = -0.385$, $P < 0.01$) were related to higher HbA_{1c} levels, while there was no association between carbohydrate intake and HbA_{1c} in the present study.

In conclusion, Korean T2DM elders should be encouraged to increase protein and fat intakes and add more variety to their usual diets to enhance glycemic control. Healthcare professionals should target nutritional education to diabetic elders and encourage them to make sustainable changes toward a healthier lifestyle and diet in order to maintain good glycemic control.

ACKNOWLEDGMENT

We would like to thank the elders for taking part and for granting consent.

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