Original Research Article

INQUIRY: The Journal of Health Care Organization, Provision, and Financing
Volume 58: 1–9

DOI: 10.1177/00469580211035727
journals.sagepub.com/home/inq

A Cross-Sectional Study of the Effects of Physical Activity and Nutrient Intakes on Blood Glucose Control Rates in Middle-Aged and Elderly Diabetes Patients: Korean National Health and Nutrition Examination Survey 2015-2017

Young Mi Kim[1,2], Jin Dong Kim[2,3] and Hana Jung[4]

Abstract

This study aimed to investigate factors affecting blood glucose control among middle-aged and older diabetic patients taking medications or receiving insulin therapy. In 2015–2017 data obtained from the Korean National Health and Nutrition Examination Survey (KNHANES), 1257 patients with diabetes were divided into a controlled group and an uncontrolled group based on blood glucose levels (cutoff ≥126 mg/dL). After adjusting for confounding factors, the BMI, total cholesterol level, and triglycerides level of the uncontrolled group were significantly higher than the controlled group. The total amount of moderate-intensity activity in controlled patients was significantly higher than that of the controlled group. Total energy, fat, saturated fatty acids, and cholesterol intakes were found to be significantly higher in the uncontrolled than controlled group. Intakes of calcium, phosphorus, potassium, riboflavin, niacin, and vitamin C were significantly lower in the uncontrolled than controlled group. Adequate nutrition intake and physical activity of patients undergoing diabetes therapy are required for effective blood glucose management for both diabetic drug and insulin therapies.

Keywords

diabetes, blood glucose control, body composition, nutrient intake, physical activity

Highlights

* What do we already know about this topic?

It is important to identify factors affecting blood glucose control among middle-aged diabetic patients taking diabetes medication or insulin therapy.

* How does your research contribute to the field?

Our investigation provided evidence of a relationship between moderate-intensity activity time, nutrient intake, and blood glucose control in diabetes patients taking medications or receiving insulin therapy.

* What are your research's implications toward theory, practice, or policy?

Clinicians should emphasize that changes in body composition affected by physical activity and adequate daily

[1]College of PARAMITA, Dongguk University, Gyeongju, Republic of Korea
[2]Shezline Medical Center, Pusan, Republic of Korea
[3]College of Education, Pusan National University, Pusan, Republic of Korea
[4]A&P Lab, Inc., Research Institute of Consilience, Seoul, Republic of Korea

Corresponding Author:
Hana Jung, Department of Natural Science, Research Institute of Consilience, A&P Lab, Inc. 343, Samil-daero, Jung-gu, Seoul 04538, Republic of Korea.
Email: hana5684@gmail.com

nutrient intake are crucial elements of diabetes management in middle-aged elderly patients.

Introduction

According to the 2018 Korean National Health and Nutrition Examination Survey (KNHANES), the prevalence of diabetes (adults, ≥30 years) is 12.9% in men and 7.9% in women; the diabetes cognitive rate was 71.5%, treatment rate was 66.2%, disease control rate was 31.1%, and treatment rate was 25.8% (for those over 30 years old).[1] Thus, the scale of diabetes treatment has continuously increased, but the diabetes control rate is lower than other chronic diseases in Korea. There are several possible contributors to poor glucose control among middle-aged and older adults, including misdiagnoses, inadequate treatment adherence, and lifestyle factors.[2] Glycemic control according to age group showed that optimal glycemic control was more prevalent among older individuals compared to younger individuals.[3] Another previous study demonstrated that individuals who had suffered diabetes for more than 10 years had a greater probability of glycemic control by 55% compared to those with diabetes for 10 years or less (OR = 1.55, $p < .05$).[4] Therefore, it is important to identify factors affecting blood glucose control among middle-aged diabetic patients.

Well-known risk factors for diabetes include unfavorable dietary intake, obesity, and biological determinants.[5] A recent study found unfavorable fat or carbohydrate intake to be associated with an increased incidence of type 2 diabetes mellitus among Korean adults.[6] The obesity rate among Koreans with diabetes is over 50%.[7] Therefore, to manage diabetes, controlling blood glucose levels using a combination of pharmacotherapy and lifestyle changes, such as weight control and diet modifications, is crucial.[8,9] The American Diabetes Association now recommends that patients with type 2 diabetes engage in aerobic exercise of moderate intensity (50% to 70% of maximal heart rate) at least 3 days a week and resistance exercise at least twice a week.[10] In Korea, a study found that combined low- and moderate-intensity aerobic exercise, such as walking for 30 minutes or more five times a week, is likely to improve glycemic control (HbA1c concentration below 6.5%) and thus prevent the acute and chronic complications of type 2 diabetes mellitus among people aged 30 to 90 years.[11] Therefore, it is important to investigate the effects of physical activity of varying frequency, duration, and intensity levels on blood glucose control among middle-aged and older diabetic patients.

In the United States of America, given that the majority of persons with type 2 diabetes are overweight or obese, weight loss through nutritional therapy is often a first step in controlling the onset or progression of diabetes.[12] The appropriate consumption of daily nutrients aids in weight loss or weight management and may improve the regulation rates of therapeutic agents that are needed to control diabetes. In addition, the correct diet may help in improving psychological health such that a patient might be encouraged to effectively manage their diabetes.[13] The American Diabetes Association recommends that patients undergoing diabetic therapy follow the dietary guidelines for the general population as set out by the Dietary Guidelines for Americans.[14] A national cross-sectional study conducted between 2005 and 2010 indicated that men and women diagnosed with diabetes consumed more protein than their counterparts with undiagnosed diabetes; however, all participants consumed less fiber and more saturated fat than recommended.[15] In United States of America, according to 1988–2004 NHANES data, about two-thirds of adults with type 2 diabetes consumed more fat and saturated fat than recommended,[16] and the total energy consumption of patients aged 45–64 years increased over time.[17]

In Korea, previous studies have also been performed to determine health-related lifestyles that influence glycemic control for diabetes mellitus management strategies. However, few studies have focused on the anthropometric status, physical activity, and nutritional intake of patients undergoing diabetic therapy in terms of adequate vs poor glucose control. Therefore, the present study investigated the body compositions, blood biochemistry profiles, physical activity, and nutrient intake of middle-aged and older patients on diabetes treatment and compared patients with good vs poor control of blood glucose levels.

Methods

Data Source and Subjects

This study is based on data from the 2015–2017 KNHANES (sixth–seventh), a cross-sectional, national survey conducted by the Korean Ministry of Health and Welfare. The KNHANES sixth–seventh vetted survey subjects using a stratified and multistage probability model designed to represent individuals over the age of one living in Korea. The survey comprised three parts: the collection of sociodemographic, health, and nutritional data through distinct surveys.[18] The Institutional Review Board (IRB) of the Korea Centers for Disease Control reviews and approves the KNHANES survey annually. The present study design was approved by the IRB of the Korean Ministry of Health and Welfare (IRB number: P01-202003-21-004).

The 2015–2017 KNHANES included 23 657 subjects; in the present study, subjects were excluded if they did not have diabetes or had missing data regarding diabetes or diabetes therapy. Furthermore, subjects were excluded if they were younger than 45 years, were pregnant, or had a daily calorie intake below 500 kcal or over 5000 kcal. The study cohort consisted of 1257 middle-aged and older patients who were diagnosed with diabetes. Subjects with diabetes were defined as those who responded "Yes" to the question "Have you been diagnosed with diabetes by a doctor at a hospital?" in the health interview survey; subjects who responded "No" were considered to not have diabetes, and subjects who responded "Not applicable" were excluded from the study. Moreover, subjects were excluded if they were not taking diabetes medication or insulin. Glucose control was classified according to blood glucose cutoff of 126 mg/dL; subjects with diabetes were categorized as either controlled or uncontrolled depending on whether their most recent fasting blood glucose measurement was below or above this threshold, respectively (Figure 1).

Variables and Measurements

Sociodemographic characteristics such as age, sex, education level, and marital status were obtained from the health interview survey. Obesity was defined as a BMI (calculated as kg/m^2) of ≥25 kg/m^2, which is the cutoff for adults in the Asian and Pacific regions.[19] Systolic and diastolic blood pressure values were measured after a resting period. Blood samples were collected from the antecubital vein after an 8 h fast. Total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), triglycerides (TG), and fasting blood glucose levels were measured using an enzymatic method (Hitachi Automatic Analyzer 7600, Hitachi, Japan).

Physical activity categories included walking, moderate-intensity exercise, and activity exerted while commuting. Physical activity indicators were taken from the KNHANES health behavior survey items. Since the study subjects were people over 45 years of age who were currently taking diabetes medication or insulin, the exercise categories were moderate-intensity physical activity (work and leisure time) and location-moving physical activity, excluding high-intensity physical activity indicators. Moderate-intensity physical activity during working hours included walking briskly while performing work activities, including paid work, unpaid work, schooling and education, household chores, farming, fishing, ranching, or job-seeking; its definition included carrying light objects, cleaning, and child-rearing (bathing, carrying a child, etc.). Moderate-intensity physical activity in leisure time included moderate-intensity sports, exercise, and leisure activities in which subjects would invariably become slightly short of breath or have a slightly raised heart rate for at least 10 minutes, such as brisk walking, light jogging (jogging), or weight training (strengthening exercises). Physical activity during commuting was defined as going to work, walking for more than 10 minutes, or using a bicycle; the definition also included the exertion involved in shopping, going to worship, among other activities.

Diet and food intake were assessed using a one-day 24 h recall method in the KNHANES. The dietary questionnaire was administered during face-to-face interviews in which information concerning the type, amount, and frequency of foods and drinks consumed during the previous day was solicited.

Statistical Analysis

Korean National Health and Nutrition Examination Survey data from the Korea National Statistical Office were used to

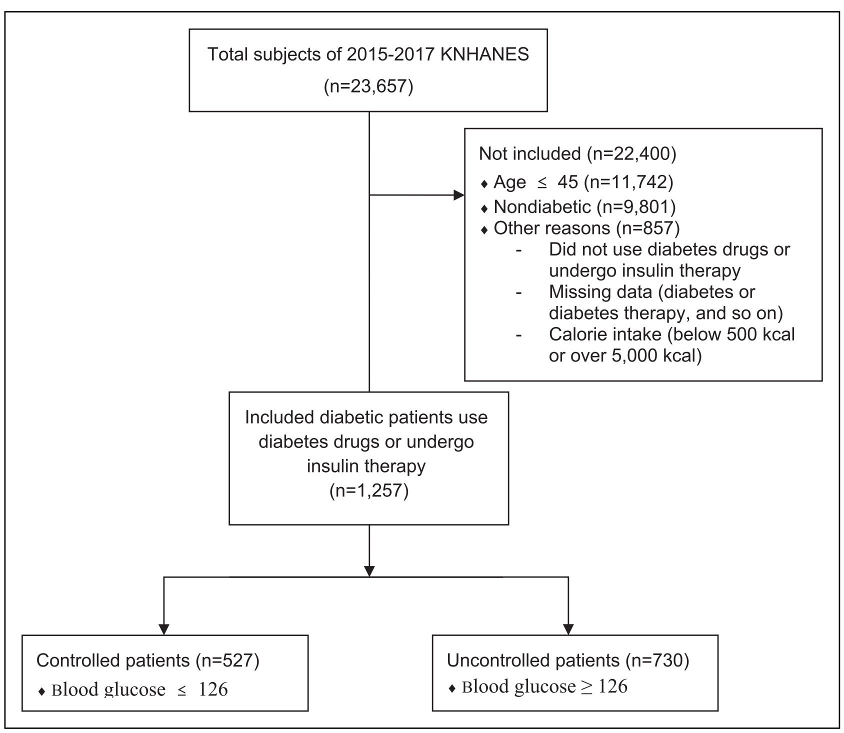

Figure 1. Flowchart of study population.

define the standard population. We used the presets of stratified random sampling (kstrata), population sampling (psu), weighted samples (wt_itvex), and performed complex sample analysis in SPSS Statistics for Windows, version 23.0 (IBM Corp, Armonk, NY, USA). Descriptive statistics for the health interview survey, health examination survey, and nutrition survey were generated in which frequencies and percentages were calculated for categorical variables, and means and standard errors were calculated for continuous variables. To determine whether differences in general characteristics, physical activity levels, anthropometric data, biochemical data, and nutrient intake existed between the controlled and uncontrolled blood glucose groups, we used the chi-square test for categorical variables (general characteristics and physical activity type) and linear regression modeling for continuous variables (physical activity time, anthropometric data, biochemical data, and nutrient intake). General linear models in complex sample analysis were used to compare the two groups (controlled and uncontrolled) according to the anthropometric and biochemical parameters, and physical activities and nutrient intake among the diabetic patients that used diabetes drugs or insulin therapy were measured after adjusting for model 1: adjusted for gender and age and model 2: adjusted for gender, age, residential area, educational level, household income level, employment status, smoking status, current alcohol consumption, obesity, hypertension, dyslipidemia, and total energy intake. Statistical significance for all analyses was set at $p < .05$.

Results

The general characteristics of the Korean diabetic patients according to blood glucose control are shown in Table 1. Among a total of 1257 subjects with diabetes, 41.9% were

Table 1. General characteristics of diabetes patients.

	Diabetes patients				
	Controlled (n=527)		Uncontrolled (n=730)		
Variables	Count (%)		Count (%)		P-value[a]
Gender					
Male	245	(39.1)	354	(60.9)	.1547
Female	282	(43.8)	376	(56.2)	
Age					
45–64	170	(37.8)	297	(62.2)	.0389
64+	357	(44.5)	433	(55.5)	
Residential area					
City	410	(42.1)	536	(57.9)	.3302
Suburbs	117	(38.1)	194	(61.9)	
Educational level					
Elementary school or less	244	(41.2)	335	(58.8)	.0777
Middle school	85	(47.4)	107	(52.6)	
High school	104	(35.0)	177	(65.0)	
College or over	69	(46.0)	83	(54.0)	
Household income level					
Low	219	(43.2)	273	(56.8)	.5916
Low–middle	137	(41.3)	187	(58.7)	
Middle–high	94	(41.6)	135	(58.4)	
High	72	(37.0)	133	(63.1)	
Employment status					
Employed	193	(38.0)	310	(62.0)	.0772
Unemployed	309	(43.9)	394	(56.1)	
Current smoking status					
Current smoker	69	(36.5)	121	(63.5)	.2696
Ex-smoker	154	(44.8)	190	(55.2)	
Non-smoker	293	(41.5)	399	(58.5)	
Current alcohol consumption					
Drinking	276	(40.0)	408	(60.0)	.2673
Non-drinking	241	(43.9)	304	(56.1)	

[a]P values are analyzed by X^2 test.

reported to be controlled and 58.1% reported uncontrolled blood glucose levels. In the patients undergoing diabetic therapy, there was a significant difference in the control rate of blood glucose between middle-aged and elderly subjects, whereby 44.5% of elderly patients controlled blood glucose levels, which was higher than the 6.7% of middle-aged patients who were considered controlled ($p < .05$). The control rate in females (43.8%) was higher than that of males (4.7%) who controlled blood glucose levels, but this was not statistically significant. There were no significant differences in gender, residential area, educational level, household income level, employment status, smoking, and alcohol consumption ($p > .05$).

Anthropometric and biochemical indicators of patients undergoing diabetic therapy are shown in Table 2. In terms of the anthropometric data, no significant differences in the obesity and hypertensive indicators were observed between the controlled and uncontrolled groups in the unadjusted model. After adjusting for confounding factors such as gender, age, residential area, educational level, household income level, employment status, smoking status, current alcohol consumption, obesity, hypertension, and dyslipidemia, the mean BMI of the uncontrolled group (25.1) was significantly higher than that of the controlled (24.8). In terms of dyslipidemia indicators, the total cholesterol and triglyceride levels of the uncontrolled group were significantly higher than those of controlled group. Regarding diabetic indicators, blood glucose and HbA1c, these factors were significantly higher in the uncontrolled group than the controlled groups in both the adjusted and unadjusted models ($p < .001$).

The physical activities of controlled and uncontrolled patients undergoing diabetic therapy are shown in Table 3. There was no statistical difference in control rate of everyday walkers and people who do not walk or who walk 1–6 times a week ($p > .05$). There was no significant difference in walking while commuting between controlled and uncontrolled groups ($p > .05$). After adjustment for confounding factors, the total amount of moderate-intensity activity during work, rest, and commuting in controlled patients was significantly higher than that of the controlled group ($p < .001$). Control rate of patients doing moderate-intensity activity during work, rest, and commuting over 240 minutes was significantly higher than that of patients under 240 minutes ($p = .049$).

The macronutrient intake of the controlled and uncontrolled patients undergoing diabetic therapy is shown in Table 4. In the unadjusted model, there was no significant difference in macronutrient intake between the two groups. After adjusting for confounding factors, the consumption of total energy, fat, saturated fatty acids, and cholesterol was found to be significantly higher in the uncontrolled group than in the controlled group, whereas there was no significant difference between the two groups in terms of the intake of monounsaturated fatty acids and n-3 fatty acids.

The mineral and vitamin intakes of the controlled and uncontrolled groups undergoing diabetic therapy are shown in Table 5. In the unadjusted model, the intake of

Table 2. Blood control status according to body composition and blood indicators in diabetes patients.

Variables	Diabetes patients: Controlled (n=527) Count (%)/mean ± SE		Diabetes patients: Uncontrolled (n=730) Count (%)/mean ± SE		P value*	P value** Model 0	P value** Model 1	P value** Model 2
Obesity indicators								
BMI	24.8	±0.2	25.1	±0.1		.1421	.1800	<.0001
Obesity (BMI≥25)	234	(41.6)	349	(58.4)	.8763			
Hypertensive indicators								
Systolic blood pressure (SBP)	124.7	±0.8	125.1	±0.7		.6568	.3212	.1991
Diastolic blood pressure (DBP)	71.9	±0.5	72.9	±0.5		.1770	.6238	<.0001
Dyslipidemia indicators								
Total cholesterol	163.8	±1.8	170.4	±1.7		.0086	.0065	<.0001
Triglyceride	144.7	±4.6	174.8	±7.3		.0007	.0011	<.0001
HDL- cholesterol	44.8	±0.6	45.3	±0.6		.5880	.4931	<.0001
LDL- cholesterol	97.2	±2.3	99.0	±2.0		.5660	.6273	.1768
Diabetes indicators								
Blood glucose	108.2	±0.7	166.1	±1.9		<.0001	<.0001	<.0001
HbA1c	6.6	±0.0	7.7	±0.1		<.0001	<.0001	<.0001

SD; standard error.
[a]P values are analyzed by X^2 test.
[b]P values are analyzed by general linear model (model 0: unadjusted, model 1: adjusted for gender and age, model 2: adjusted for gender, age, residential area, educational level, household income level, employment status, smoking status, current alcohol consumption, obesity, hypertension, and dyslipidemia).

Table 3. Blood control status according to physical activities in diabetes patients.

Variables	Diabetes patients: Controlled (n=527) Count (%)/mean ± SE		Diabetes patients: Uncontrolled (n=730) Count (%)/mean ± SE		*P* value*	*P* value**: Model 0	Model 1	Model 2
Walking					.3347			
No	131	(43.7)	187	(56.3)				
1~6/week	224	(38.5)	331	(61.5)				
Everyday	145	(42.9)	185	(57.1)				
Moderate-intensity in work					.1145			
Yes	34	(52.9)	25	(47.1)				
No	470	(40.5)	682	(59.5)				
Activity time/week (min)	402.0	±55.6	352.7	±78.4			-	-
Moderate intensity in rest					.1942			
Yes	82	(46.6)	87	(53.4)				
No	422	(40.1)	619	(59.9)				
Activity time/week (min)	188.4	±10.5	216.4	±18.6		<.0001	<.0001	.7923
Moderate intensity in commuting					.3375			
Yes	256	(42.7)	347	(57.3)				
No	248	(39.5)	359	(60.5)				
Activity time/week (min)	196.1	±6.5	204.9	±13.1		.7377	.7290	<.0001
Moderate intensity in work and rest/week (min)	269.4	±29.2	226.3	±43.0		<.0001	<.0001	<.0001
Moderate intensity in work, rest, and commuting/week (min)	272.8	±18.2	231.8	±18.3		.1133	.0867	<.0001
				.0493				
≥240 min	106	(47.5)	121	(52.6)				
<240 min	395	(39.4)	583	(60.6)				

SD; standard deviation.
[a]P values are analyzed by X^2 test.
[b]P values are analyzed by general linear model (model 0: unadjusted, model 1: adjusted for gender and age, model 2: adjusted for gender, age, residential area, educational level, household income level, employment status, smoking status, current alcohol consumption, obesity, hypertension, and dyslipidemia).

riboflavin in the uncontrolled group was significantly lower than that of the controlled group. After adjusting for confounding factors, the consumption of calcium, phosphorus, potassium, riboflavin, niacin, and vitamin C was found to be significantly lower in the uncontrolled group than the controlled group, whereas the intake of vitamin A and carotene was significantly higher in the uncontrolled patients rather than controlled groups.

Discussion

Controlling blood glucose levels using a combination of pharmacotherapy and lifestyle changes, such as weight control and diet modifications such as low-carbohydrate, fiber-rich, and high-protein diet, is crucial for diabetes management.[20-22] The present study evaluated anthropometric data, blood lipid concentrations, physical activity, and nutrient intake of patients undergoing diabetic therapy and compared their controlled and uncontrolled blood glucose levels by using data from the 2015–2017 KNHANES.

In this study, among 1257 subjects undergoing diabetic therapy, 527 (41.9%) patients controlled their blood glucose levels. This rate was higher than the 25.8% control rate published in the KNHANES for patients aged over 30 years from 2016 to 2018.[1] The difference is that in the KNHANES, the measurement of controlled glucose levels in diabetic patients was based on glycated hemoglobin (less than 6.5%), and blood glucose was the standard in this study. In the patients undergoing diabetic therapy, there was a significant difference in the control rate of blood glucose between middle-aged and elderly subjects, whereby 44.5% of elderly patients controlled glucose levels, which was higher than the 6.7% of middle-aged who controlled their glucose levels. Similar results have been reported in prior studies on glycemic control according to age group. Glycemic control according to age group showed optimal glycemic control was more prevalent among older individuals compared to younger individuals.[3] In other previous studies, individuals who had suffered diabetes for more than 10 years had a greater probability of glycemic control by 55% compared to those

Table 4. Macronutrient intakes of diabetes patients.

	Diabetes patients					
	Controlled (n=527)		Uncontrolled (n=730)		P-value[a]	
	Mean±standard error		Mean±standard error		Model 1	Model 2
Macronutrient intake						
Energy intake (Kcal)	1699.5	±40.7	1735.6	±35.4	.8172	.0338
Carbohydrate (g)	291.9	±6.6	284.0	±5.3	.1239	<.0001
Protein (g)	57.8	±1.7	58.8	±1.5	.6318	<.0001
Fat (g)	30.4	±1.3	31.1	±1.3	.6682	<.0001
Saturated fatty acid (g)	8.7	±0.4	9.0	±0.4	.7643	<.0001
Monounsaturated fatty acid (g)	9.2	±0.5	9.4	±0.5	.5732	.5671
Polyunsaturated fatty acid (g)	8.2	±0.3	8.4	±0.3	.7620	<.0001
n-3 fatty acid (g)	1.5	±0.1	1.5	±0.1	.2669	.1090
n-6 fatty acid (g)	6.7	±0.3	7.0	±0.3	.9879	<.0001
Cholesterol (mg)	156.4	±12.1	167.0	±8.7	.8767	<.0001

[a]P values are analyzed by general linear model (model1: adjusted for gender and age, model2: adjusted for gender, age, residential area, educational level, household income level, employment status, smoking status, current alcohol consumption, obesity, hypertension, dyslipidemia, and total energy intake).

Table 5. Micronutrient intakes of diabetes patients.

	Diabetes patients					
	Controlled (n=527)		Uncontrolled (n=730)		P-value[a]	
	Mean±standard error		Mean±standard error		Model 1	Model 2
Mineral intake						
Calcium (mg)	440.2	±15.1	432.2	±11.5	.2896	<.0001
Phosphorus (mg)	940.2	±25.4	933.9	±20.5	.2666	<.0001
Iron (mg)	14.9	±0.5	15.0	±0.6	.7185	.1244
Sodium (mg)	3206.9	±115.7	3453.6	±104.7	.3529	.0023
Potassium (mg)	2798.5	±75.2	2697.2	±63.0	.0790	<.0001
Vitamin intake						
Vitamin A (μgRE)	461.5	±25.1	526.1	±38.1	.1777	<.0001
Carotene (μg)	2830.5	±155.4	3221.2	±222.3	.1766	<.0001
Retinol (μg)	64.3	±5.3	66.3	±6.3	.9699	.1175
Thiamine (mg)	1.6	±0.0	1.6	±0.0	.4658	.2961
Riboflavin (mg)	1.2	±0.0	1.1	±0.0	.0497	<.0001
Niacin (mg)	12.8	±0.4	12.6	±0.3	.2488	<.0001
Vitamin C (mg)	89.3	±5.1	78.6	±4.3	.0627	<.0001

[a]P values are analyzed by general linear model (model1: adjusted for gender and age, model2: adjusted for gender, age, residential area, educational level, household income level, employment status, smoking status, current alcohol consumption, obesity, hypertension, dyslipidemia, and total energy intake).

with diabetes for 10 years or less (OR = 1.55, $p < .05$).[4] These results show that middle-aged patients with early diagnosis of diabetes do not fully understand or practice self-management rules for glycemic control.

The majority of persons with type 2 diabetes are overweight or obese; weight loss through physical activity and nutritional therapy is often a first step to control diabetes worldwide.[12,23,24] However, approximately 50% of diabetic patients being treated in this study were obese; the mean BMI of the uncontrolled patients (25.1) was significantly higher than that of the controlled patients (24.8) after adjusting for confounding factors. Besides, the total cholesterol and triglyceride levels of the uncontrolled group were significantly higher than those of the controlled group. The results of this study are consistent with the results that the BMI of the glycemic control group (25.0) was significantly lower than the non-glycemic control group (25.5) in Korean diabetic patients.[7] Therefore, appropriate daily habits, such as physical activity, and appropriate nutrient intake to aid in weight management may affect the insulin and antihyperglycemic medication doses required to control glucose levels.[13]

The American Diabetes Association now recommends that patients with type 2 diabetes engage in moderate aerobic exercise.[10] In Korea, a study demonstrated that combined low- and moderate-intensity aerobic exercise improves HbA1c concentrations among people with type 2 diabetes mellitus between the age of 30 and 90 years.[11] In the present study, the total amount of moderate-intensity exercise during work, leisure, and commuting among controlled patients was significantly higher than that among uncontrolled patients, and the control rate among patients engaging in moderate-intensity exercise during work, leisure, and commuting for over 240 minutes per week was significantly higher than that among patients with less than 240 minutes of such activity per week. These findings demonstrate the importance of investigating the effects of exercise according to intensity levels, frequency, and duration on blood glucose control among middle-aged and older diabetic patients.

The American Diabetes Association also recommends that patients undergoing diabetic therapy follow the dietary guidelines for the general population.[14] However, in the present study, the total energy, fat, saturated fatty acid, and cholesterol consumption in the uncontrolled group was significantly higher than that in the controlled group after adjusting for confounding factors and energy intake. A national cross-sectional study revealed that diabetes patients consumed more saturated fat than recommended.[15] About two-thirds of type 2 diabetes patients consume more fat and saturated fat than recommended.[16] Several micronutrients are known to be important in the management of diabetes.[25-27] For example, there are meta-analyses demonstrating that low calcium levels may negatively affect glycemic levels.[28] Potassium and vitamin C are found in a variety of fruits and vegetables, and potassium may influence insulin secretion.[29] In this study, the consumption of calcium, phosphorus, potassium, riboflavin, niacin, and vitamin C in the uncontrolled group was found to be significantly lower than that in the controlled group after adjusting for confounding factors and energy intake. The intake of water-soluble vitamins in the uncontrolled group was significantly lower than that in the controlled group. These results show that the intake of some micronutrients and water-soluble vitamins may be beneficial for blood sugar control.

The current study had several strengths. First, our investigation provided evidence of a relationship between moderate-intensity activity time and blood glucose control in diabetes patients taking medications or receiving insulin therapy. Second, this study focused on the association of macro and micronutrient intake with blood glucose control in diabetes patients. Finally, our study was a national population-based analysis using KNHANES data, which strengthens the statistical reliability of the results and data. However, the present study has some limitations, which should be researched by further investigation. First, this cross-sectional study design did not allow us to make conclusions regarding the causal relationships between blood glucose control and physical activities or nutrient intakes. Second, this study identified only one blood glucose as an indicator of glycemic control. Future studies should investigate using various glycemic control parameters including hemoglobin A1c, glycated albumin, and fructosamine.

In summary, the findings of the present study support recommendations for patients with diabetes to engage in moderate-intensity physical activity while going about their daily routines (work, leisure, and commuting). The findings also emphasize the importance of certain micronutrients for blood glucose management among middle-aged and older patients on diabetes treatment. The results indicate that changes in body composition effected by physical activity and adequate daily nutrient intake are crucial elements of diabetes management. Clinicians should emphasize the importance of appropriate physical activity and nutrient intake to their patients in addition to providing education on diabetes therapeutics.

Acknowledgments

This work was conducted in collaboration with researchers from Shezline Medical Center and Research Institute of A&P Lab, Inc. The authors and researchers thank the two institutions.

Author Disclosure

The present study design was approved by the Institutional Review Board of the Korean Ministry of Health and Welfare (IRB number: P01-202003-21-004). Consent for publication: Not applicable.

Authors' contributions

YM Kim:
Contributions: undertook data collection, analysis, interpretation, and manuscript writing.
JD Kim:
Contribution: undertook data collection analysis, interpretation, and manuscript writing.
HN Jung:
Contribution: conceived the study question and contributed to the study design, supervised data collection, analysis, interpretation, and manuscript writing.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

ORCID iD

Hana Jung https://orcid.org/0000-0003-1973-7515

References

1. Ministry of Health and Welfare of Korea. *Korean National Health and Nutrition Examination Survey*; 2018.
2. Schlenk EA, Dunbar-Jacob J, Engberg S. Medication non-adherence among older adults: a review of strategies and interventions for improvement. *J Gerontol Nurs*. 2004; 30(7):33-43.
3. Comellas M, Marrero Y, George F, Matthews L. Age and glycemic control among adults with type 2 diabetes in the United States: an assessment from the national health and nutrition examination survey (NHANES) 2013-2014. *Diabetes Metab Syndr*. 2019;13(6):3069-3073.
4. Barrot-de la Puente J, Mata-Cases M, Franch-Nadal J, et al. Older type 2 diabetic patients are more likely to achieve glycaemic and cardiovascular risk factors targets than younger patients: analysis of a primary care database. *Int J Clin Pract*. 2015;69(12):1486-1495.
5. Wang J, Hong Z, Wu L, et al. Dietary intake and cardiometabolic biomarkers in relation to insulin resistance and hypertension in a middle-aged and elderly population in Beijing, China. *Appl Physiol Nutr Metabol*. 2017;42(8):869-875.
6. Ha K, Joung H, Song Y. Inadequate fat or carbohydrate intake was associated with an increased incidence of type 2 diabetes mellitus in Korean adults: a 12-year community-based prospective cohort study. *Diabetes Res Clin Pract*. 2019;148:254-261.
7. Kim Y, Cho E. Lifestyle factors related to glucose control for diabetes management strategies: nested case control design using KNHANES data. *Journal of the Korea Convergence Society*. 2019;10(11):501-510.
8. European Association for Cardiovascular, Catapano AL, Reiner Z, De Backer G, et al. ESC/EAS Guidelines for the management of dyslipidaemias: the Task Force for the management of dyslipidaemias of the European society of cardiology (ESC) and the European atherosclerosis society (EAS). *Atherosclerosis*. 2011; 217 Suppl 1(14):S1-S44.
9. Stone NJ, Robinson JG, Lichtenstein AH, et al. 2013 ACC/AHA guideline on the treatment of blood cholesterol to reduce atherosclerotic cardiovascular risk in adults: a report of the American college of cardiology/American heart association task force on practice guidelines. *J Am Coll Cardiol*. 2013; 63(25 Pt B):2889-2934.
10. Association AD. Standards of medical care in diabetes-2015 abridged for primary care providers. *Clin Diabetes*. 33;2015:97-111.
11. Park JH, Lee Y-E, Lee YE. Effects of exercise on glycemic control in type 2 diabetes mellitus in Koreans: the fifth Korea national health and nutrition examination survey (KNHANES V). *J Phys Ther Sci*. 2015;27(11):3559-3564.
12. Evert AB, Boucher JL, Cypress M, et al. Nutrition therapy recommendations for the management of adults with diabetes. *Diabetes Care*. 2014;37 Suppl 1(suppl 1Supplement 1):S120-S143.
13. Casagrande SS, Cowie CC. Trends in dietary intake among adults with type 2 diabetes: NHANES 1988-2012. *J Hum Nutr Diet*. 2017;30(4):479-489.
14. Committee USDGA. *Dietary Guidelines for Americans*. US Department of Health and Human Services, US Department of Agriculture; 2010.
15. Bardenheier BH, Cogswell ME, Gregg EW, Williams DE, Zhang Z, Geiss LS. Does knowing one's elevated glycemic status make a difference in macronutrient intake?. *Diabetes Care*. 2014;37(12):3143-3149.
16. Nelson KM, Reiber G, Boyko EJ. Diet and exercise among adults with type 2 diabetes: findings from the third national health and nutrition examination survey (NHANES III). *Diabetes Care*. 2002;25(10):1722-1728.
17. Oza-Frank R, Cheng YJ, Narayan KM, Gregg EW. Trends in nutrient intake among adults with diabetes in the United States: 1988-2004. *J Am Diet Assoc*. 2009;109(7):1173-1178.
18. Kweon S, Kim Y, Jang MJ, et al. Data resource profile: the Korea national health and nutrition examination survey (KNHANES). *Int J Epidemiol*. 2014;43(1):69-77.
19. Bassett J, Organization WH. *The Asia-Pacific Perspective: Redefining Obesity and its Treatment*. Health Communications Australia; 2000.
20. Gannon MC, Nuttall FQ. Effect of a high-protein, low-carbohydrate diet on blood glucose control in people with type 2 diabetes. *Diabetes*. 2004;53(9):2375-2382.
21. Giacco R, Parillo M, Rivellese AA, et al. Long-term dietary treatment with increased amounts of fiber-rich low-glycemic index natural foods improves blood glucose control and reduces the number of hypoglycemic events in type 1 diabetic patients. *Diabetes Care*. 2000;23(10):1461-1466.
22. Smith DE, Heckemeyer CM, Kratt PP, Mason DA. Motivational interviewing to improve adherence to a behavioral weight-control program for older obese women with NIDDM. A pilot study. *Diabetes Care*. 1997;20(1):52-54.
23. Campbell L, Rössner S. Management of obesity in patients with Type 2 diabetes. *Diabet Med*. 2001;18(5):345-354.
24. Fujioka K, Seaton TB, Rowe E, et al. Weight loss with sibutramine improves glycaemic control and other metabolic parameters in obese patients with type 2 diabetes mellitus. *Diabetes Obes Metabol*. 2000;2(3):175-187.
25. Thompson KH, Godin DV. Micronutrients and antioxidants in the progression of diabetes. *Nutr Res*. 1995;15(9):1377-1410.
26. Thalassinos NC, Hadjiyanni P, Tzanela M, Alevizaki C, Philokiprou D. Calcium metabolism in diabetes mellitus: effect of improved blood glucose control. *Diabet Med*. 1993;10(4):341-344.
27. Krempf M, Ranganathan S, Ritz P, Morin M, Charbonnel B. Plasma vitamin A and E in type 1 (insulin-dependent) and type 2 (non-insulin-dependent) adult diabetic patients. *Int J Vitam Nutr Res*. 1991;61(1):38-42.
28. Pittas AG, Lau J, Hu FB, Dawson-Hughes B. The role of vitamin D and calcium in type 2 diabetes. A systematic review and meta-analysis. *J Clin Endocrinol Metab*. 2007;92(6):2017-2029.
29. Chatterjee R, Yeh HC, Shafi T, et al. Serum and dietary potassium and risk of incident type 2 diabetes mellitus: The atherosclerosis risk in communities (ARIC) study. *Arch Intern Med*. 2010;170(19):1745-1751.