Original Article

Effects of exercise on glycemic control in type 2 diabetes mellitus in Koreans: the fifth Korea National Health and Nutrition Examination Survey (KNHANES V)

Ji-Hye Park, PhD[1]), Young-Eun Lee, PhD[1])*

[1]) *Department of Dental Hygiene, Daegu Health College: 15 Youngsong-Ro, Buk-Gu, Daegu 702-722, Republic of Korea*

Abstract. [Purpose] The aim of this study was to investigate the effect of exercise on glycemic control using data from fifth Korea National Health and Nutrition Examination Survey and to provide appropriate exercise guidelines for patients with type 2 diabetes mellitus in Korea. [Subjects and Methods] We selected 1,328 patients from the fifth Korea National Health and Nutrition Examination Survey database who had type 2 diabetes and ranged in age from 30 to 90 years. Statistical analyses included χ^2 tests, multiple linear regression, and logistic regression. [Results] Factors found to be significantly related to glycemic control included income level, physical activity based on intensity of aerobic exercise, use of diabetes medicine, presence of hypertension, duration of diabetes, and waist circumference. In addition, engaging in combined low- and moderate-intensity aerobic exercise when adjusted for resistance exercise was found to lower the risk of glycemic control failure. [Conclusion] Patients with type 2 diabetes mellitus in Korea should engage in combined low- and moderate-intensity aerobic exercise such as walking for 30 minutes or more five times a week. Physical activity is likely to improve glycemic control and thus prevent the acute and chronic complications of diabetes mellitus.
Key words: Exercise, Glycemic control, Type 2 diabetes mellitus

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INTRODUCTION

The number of persons with diabetes continues to increase worldwide[1, 2]. Diabetes, a metabolic disorder characterized by hyperglycemia, is divided into two types. Type 1 diabetes occurs when the pancreas fails to secrete insulin, and type 2 diabetes occurs when the pancreas retains some capacity to secrete insulin but insulin resistance is increased for a variety of reasons[3, 4]. Insulin controls blood glucose by facilitating glucose intake or inhibiting glucogenesis. Insulin resistance is a condition in which the action of insulin is decreased, although the level of insulin is not insufficient[5]. Chronic hyperglycemia is definitely related to complications of diabetes that damage the kidneys, eyes, nerves, heart, and blood vessels[6, 7]. Therefore, glycemic control is the most fundamental way to manage this disease.

Exercise has been considered one of the three cornerstones in the management of diabetes, the other two being dietary measures and drug therapies[8, 9]. The American Diabetes Association (ADA)[10] now recommends that patients with type 2 diabetes engage in moderate to rigorous aerobic exercise of moderate intensity (50 to 70% of maximal heart rate) for at least 150 minutes spread out over at least three days a week, with no more than two consecutive days between exercise sessions. Resistance exercises at least twice a week on nonconsecutive days are also recommended. Exercise can rapidly increase the expression of GLUT4 (glucose transporter type 4), the sugar transporter in skeletal muscles, thus increasing the activity of AMPK (adenosine monophosphate-activated protein kinase) in these muscles[11, 12]. Although patients with type 2 diabetes have a defect in insulin signal transmission in the skeletal muscles, the exercise-induced activation of AMPK in these muscles can achieve normal action[13], and the oxidation of fatty acids and glucose absorption will be accelerated[14]. The increase in insulin sensitivity after exercise is known to be maintained for about 60 hours and returns to pre-exercise levels after 3 to 5 days. However, when exercise of moderate intensity is repeatedly performed, the ability to maintain greater insulin sensitivity can be extended. Thus, repeating exercise within a time interval of 48 to 60 hours may help control blood glucose levels over the long term[15]. In a meta-analysis of the results of 16 randomized controlled trials (RCTs), Qiu et al.[16] found that walking lowered the concentration of glycated hemoglobin (HbA1c) in patients with type 2 diabetes. Measurement of a person's HbA1c concentration

*Corresponding author. Young-Eun Lee (E-mail: yelee@dhc.ac.kr)

reflects the average glucose concentration for the past 2 to 3 months. An HbA1c level lower than 6.5% is considered good control. A decrease in HbA1c of 1% can decrease the occurrence of the major cardiovascular diseases by 15 to 20%[17] and the occurrence of microvascular complications by 37%[18]. A meta-analysis of studies involving 12 aerobic exercises and 2 resistance exercises conducted by Boulé et al.[19] revealed that the HbA1c concentration in their exercise group was 0.66% lower than that in their control group after an intervention in patients with type 2 diabetes (p < 0.001). In a review of the literature by Eves and Plotnikoff[20], a prescription of resistance exercise was found to improve both glycemic control and insulin sensitivity in patients type 2 diabetes. However, it was difficult to generalize their results because most of the studies they reviewed were individually conducted under the supervision of experts and the sample sizes were relatively small. Thus, based on the studies cited above, large-scale, population-based studies are still needed to determine the best approach to glycemic control by means of exercise. Thomas et al.[21] conducted a meta-analysis of 14 RCTs and found that exercise could decrease the concentration of HbA1c in patients with type 2 diabetes by 0.6% as compared with controls (p < 0.05). Although a number of studies on exercise and glycemic control have been conducted, such research using national data are lacking. Therefore, our objectives were to investigate the effect of exercise (physical activity) on glycemic control using data from the fifth Korea National Health and Nutrition Examination Survey (KNHANES V) and to provide appropriate exercise guidelines for patients with type 2 diabetes in Korea.

SUBJECTS AND METHODS

Subjects

This study used raw data from the KNHANES V, a survey conducted in 2010 to 2012[22]. Use of this survey was approved by the Korea Center for Disease Control and Prevention (KCDC) Research Ethics Review Committee (2010-02CON-21-C, 2011-02CON-06-C, 2012-01EXP-01-2C). Written informed consent was obtained from all participants. KNHANES V surveyed three areas: health, nutrition, and health examination. Because there is no factor in the KNHANES for identifying the type of diabetes a person might have, subjects under 29 years of age who had been diagnosed with diabetes were assumed to have type 1 diabetes based on an existing national study of epidemiological characteristics of diabetes in Korea[23]. Out of a total 25,534 subjects, we therefore excluded those who had been diagnosed before the age of 29. A total of 1,328 patients given a diagnosis of type 2 diabetes at age 30 or older based on fasting glucose level, HbA1c concentration, and a physician's diagnosis were selected for study (Fig. 1).

Methods

The criteria for glycemic control were an HbA1c concentration below 6.5%, the goal set by the International Diabetes Federation[24] and the Korean Diabetes Association[3]. Physical activity was classified into six groups: no physical activity, walking, moderate activity, vigorous activity, walking plus moderate activity, and walking plus vigorous activity.
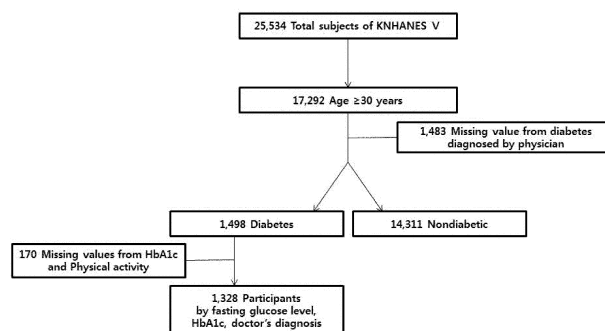

Fig. 1. Study population framework

Walking consisted of sessions of 30 minutes or more 5 days a week during a recent week and included all forms of walking (e.g., when commuting, in daily activities, and as exercise). Moderate physical activity consisted of activity that was more strenuous or made one breathe harder than usual and involved 30-minute sessions five times or more a week during a recent week (e.g., slow swimming, playing tennis doubles, volleyball, badminton, table tennis, transporting light objects, etc.). Vigorous physical activity referred to engaging in intense physical activity that made one very tired or breathe much harder than usual and involved 20-minute sessions (or longer each time) 3 days a week during a recent week (e.g., running, jogging, mountain climbing, fast cycling, fast swimming, playing soccer, playing basketball, skipping rope, playing squash or singles tennis, transporting heavy objects, etc.). Resistance exercise meant doing push-ups or sit-ups or lifting dumbbells or barbells twice or more per week during a recent week.

Smokers were defined as subjects who were currently smoking or those who had smoked 100 cigarettes (5 packs) at some time. Drinkers were defined as those who consumed one glass of an alcoholic beverage or more during their lifetime. A family history of diabetes was defined as having parents, brothers, or sisters who have or had diabetes.

Data were analyzed using PASW Statistics version 18.0 (SPSS Inc., Chicago, IL, USA). The level of significance was set at p < 0.05. To identify the relationship between glycemic control and other factors, we performed chi-square tests (χ^2-tests) and multiple linear regressions analyses. To investigate the effect of each factor on glycemic control after adjustment, logistic regression analyses were carried out.

RESULTS

The 1,328 subjects included 677 (53.6%) males and 651 (46.4%) females with a mean age of 61.8 years. Of these subjects, 23.8% had a history of smoking, and 79.5% had a history of alcohol consumption. With regard to exercise, 28.6% of the subjects performed low-intensity aerobic exercises such as walking, 2.8% performed moderate-intensity aerobic exercise, and 5.0% performed high-intensity (vigorous) aerobic exercise; 2.8% of subjects combined walking with moderate aerobic exercise, and 4.6% combined walking with vigorous aerobic exercise. A total of 34.8% had a family history of diabetes, and 96.4% took oral hypogly-

cemic agents. The percentages of subjects with high blood pressure, stroke, coronary artery disease, and chronic kidney disease were 56.7%, 5.5%, 8.8%, and 0.9%, respectively. The mean duration of diabetes was 7.9 years, and the mean concentration of HbA1c was 7.4%. The mean waist circumference was 87.0 cm, and the mean BMI was 24.9. Daily fat intake averaged 30.2 g, and daily carbohydrate intake averaged 317.1 g (Table 1).

The mean age of subjects whose HbA1c concentration was 6.4% or lower was 63.6 years, and that of subjects whose HbA1c concentration was 6.5% or higher was 61.1 years (p = 0.007). The mean duration of diabetes in the subjects whose HbA1c concentration was 6.4% or below was 6.2 years compared with the mean duration of 8.6 years for those whose HbA1c concentration was 6.5% or above, a significant difference (p < 0.001). The mean waist circumference was 85.1 cm in subjects with HbA1c concentrations of 6.4% or lower compared with the mean circumference of 87.7 cm in those with HbA1c concentrations of 6.5% or higher, indicating a significant difference between two groups (p < 0.001). Also statistically significant was the difference between these two groups in their mean BMI values: 24.2 in the subjects with HbA1c concentrations of 6.4% or lower versus 25.1 in those with an HbA1c value of 6.5% or higher (p = 0.003). The daily carbohydrate intakes in these two groups of subjects were 298.0 g and 324.1 g, respectively (p = 0.006). Education level, family history of diabetes, and presence of hypertension were also found to be related to glycemic control (p < 0.05) (Table 2).

On logistic regression analysis with glycemic control as a dependent variable, we found that income level, physical activity according to intensity of aerobic exercise, use of diabetes medicine, presence of hypertension, duration of diabetes, and waist circumference were related to glycemic control after adjusting for all factors, and these relationships were statistically significant (p < 0.05) (Table 3).

DISCUSSION

Because reinforcing insulin action, absorbing glucose into muscle by aerobic exercise, and increasing the amount of muscle by resistance exercise are all effective in decreasing glucose, combining aerobic exercise and resistance exercise is thought to facilitate glycemic control more effectively than one type of exercise alone[25]. Snowling and Hopkins[26] conducted a meta-analysis of the results from 27 RCTs and concluded that aerobic, resistance, and combined exercises all had beneficial effects on glycemic control in patients with type 2 diabetes. However, combination exercises provided additional benefits.

In our study, the number of subjects whose HbA1c concentration was 6.4% or below was 349 (27.0%), as compared with the 979 (73.0%) subjects whose HbA1c concentration was 6.5% or above, indicating that about 3/4 of the entire cohort did not have proper glycemic control. In addition, 702 (56.2%) subjects performed no exercise at all.

After adjusting for all variables in the logistic regression analysis, with glycemic control as a dependent variable, the factors found to be related to glycemic control with statistical significance included income level, physical activity according to intensity of aerobic exercise, use of diabetes medicine, presence of hypertension, duration of diabetes, and waist circumference (p < 0.05). Obesity, lack of exercise, and unhealthy dietary habits associated with low socioeconomic status (SES)[27] can be responsible for type 2 diabetes. In this study, we found that the risk of failure of glycemic control in subjects with a middle-to-high income was 2.115 times

Table 1. Characteristics of the patients with diabetes (N=1,328)

Characteristics		N	%
Gender	Male	677	53.6
	Female	651	46.4
Age, yr	Mean±SD	61.76±0.41	
Quartile of household income	Low	462	31.8
	Middle-low	332	26.1
	Middle-high	267	21.8
	High	257	20.3
Education level	Elementary	630	44.9
	Middle school	216	16.5
	High school	311	25.6
	College	170	13.0
Smoking history	No	1,056	76.2
	Yes	268	23.8
Alcohol history	No	313	20.5
	Yes	1,012	79.5
Physical activity	No activity	702	56.2
	Walking	391	28.6
	Moderate	41	2.8
	Vigorous	55	5.0
	Walking+moderate	38	2.8
	Walking+vigorous	60	4.6
	Walking+vigorous	60	4.6
Resistance training	No	993	75.1
	Yes	330	24.9
Family history of DM	No	728	65.2
	Yes	325	34.8
Oral hypoglycemic agent	No	51	3.6
	Yes	1,144	96.4
Hypertension	No	516	43.3
	Yes	811	56.7
Stroke	No	1,243	94.5
	Yes	84	5.5
Coronary artery disease	No	1,192	91.2
	Yes	135	8.8
Chronic kidney disease	No	1,317	99.1
	Yes	11	0.9
DM duration, yr	Mean±SD	7.93±0.24	
HbA1c, %	Mean±SD	7.38±0.05	
Waist circumference, cm	Mean±SD	86.98±0.36	
Body mass index, kg/m^2	Mean±SD	24.86±0.15	
Daily fat intake, g	Mean±SD	30.22±0.93	
Daily carbohydrate intake, g	Mean±SD	317.08±4.55	

Unweighted number, weighted %. DM: diabetes mellitus

Table 2. Relationship between glycemic control according to HbA1c concentration and other factors (N=1,328)

Characteristic		Glycemic control	
		HbA1c≥6.5	HbA1c<6.5
Gender	Male	502 (74.5)	175 (25.5)
	Female	477 (71.3)	174 (28.7)
Age, yrs**	Mean±SD	61.08±0.44	63.58±0.85
Quartile of household income	Low	317 (68.0)	145 (32.0)
	Middle-low	215 (73.5)	81 (26.5)
	Middle-high	206 (76.8)	61 (23.2)
	High	197 (76.0)	60 (24.0)
Education level*	Elementary	443 (67.8)	187 (32.2)
	Middle school	168 (75.9)	48 (24.1)
	High school	238 (77.7)	73 (22.3)
	College	130 (79.1)	40 (20.9)
Smoking history	No	771 (72.6)	285 (27.4)
	Yes	207 (75.1)	61 (24.9)
Alcohol history	No	239 (75.8)	74 (24.2)
	Yes	739 (72.5)	273 (27.5)
Physical activity	No activity	517 (73.7)	185 (26.3)
	Walking	298 (75.0)	93 (25.0)
	Moderate	29 (62.7)	12 (37.3)
	Vigorous	38 (68.5)	17 (31.5)
	Walking+moderate	25 (52.7)	13 (47.3)
	Walking+vigorous	47 (79.0)	13 (21.0)
	Walking+vigorous	47 (79.0)	13 (21.0)
Resistance training	No	734 (73.4)	259 (26.6)
	Yes	244 (73.0)	86 (27.0)
Family history of DM*	No	539 (72.2)	189 (27.8)
	Yes	250 (79.3)	75 (20.7)
Oral hypoglycemic agent	No	42 (85.4)	9 (14.6)
	Yes	864 (74.7)	280 (25.3)
Hypertension**	No	401 (77.9)	115 (22.1)
	Yes	577 (69.3)	234 (30.7)
Stroke	No	919 (73.2)	324 (26.8)
	Yes	59 (71.0)	25 (29.0)
Coronary artery disease	No	886 (73.4)	306 (26.6)
	Yes	92 (68.9)	43 (31.1)
Chronic kidney disease	No	970 (72.9)	347 (27.1)
	Yes	9 (85.6)	2 (14.4)
DM duration, yrs***	Mean±SD	8.57±0.27	6.20±0.41
Waist circumference, cm***	Mean±SD	87.67±0.46	85.10±0.54
Body mass index, kg/m^{2}**	Mean±SD	25.10±0.18	24.22±0.22
Daily fat intake, g	Mean±SD	31.16±1.12	27.64±1.87
Daily carbohydrate intake, g**	Mean±SD	324.05±5.56	298.02±7.63

Unweighted number, weighted %. DM: diabetes mellitus
*$p < 0.05$ by χ^2 test; **$p < 0.01$ by χ^2 test; ***$p < 0.001$ by χ^2 test

higher than that in subjects with a high income. If a patient with type 2 diabetes gets moderate exercise, the amount of glucose in peripheral use will become greater than the level of glucogenesis in the liver, thus decreasing blood glucose. Although the secretion of blood insulin is also decreased, hypoglycemia will rarely occur[15]. However, high-intensity aerobic exercise can promote glucogenesis and induce hyperglycemia by increasing the concentration of blood catecholamine. Exercise-induced hyperglycemia can continue for about 1 to 2 hours[28–30]. In this study, performance of low- and moderate-intensity aerobic exercises at the same time was found to lower the risk of glycemic control failure

Table 3. Relationship between glycemic control and other factors based on logistic regression analysis (N=1,328)

Characteristic		Odds ratio	95% CI
Gender	Male	0.927	0.561–1.531
	Female	1.000	
Age, yr	Mean±SD	1.001	0.975–1.028
Quartile of household Income	Low	0.987	0.488–1.995
	Middle-low	1.411	0.762–2.610
	Middle-high*	2.115	1.081–4.139
	High	1.000	
Education level	Elementary	0.629	0.298–1.329
	Middle school	1.142	0.515–2.533
	High school	0.757	0.381–1.565
	College	1.000	
Smoking history	No	0.686	0.397–1.183
	Yes	1.000	
Alcohol history	No	1.640	0.985–2.733
	Yes	1.000	
Physical activity	No activity	1.000	
	Walking	1.404	0.874–2.256
	Moderate*	0.317	0.103–0.982
	Vigorous	0.790	0.332–1.879
	Walking+moderate*	0.248	0.084–0.734
	Walking+vigorous	1.415	0.437–4.583
Resistance training	No	1.273	0.788–2.055
	Yes	1.000	
Family history of DM	No	0.947	0.603–1.489
	Yes	1.000	
DM medication	No medication	1.000	
	Only insulin***	20.406	4.533–91.855
	Only OHA**	2.636	1.497–4.640
	Insulin+OHA**	19.301	3.352–111.131
Hypertension***	No	2.440	1.574–3.785
	Yes	1.000	
DM duration, yrs**	Mean±SD	1.047	1.014–1.081
Waist circumference, cm*	Mean±SD	1.027	1.006–1.049
Daily carbohydrate intake, g*	Mean±SD	1.002	1.000–1.003

*$p < 0.05$ by multiple linear regression analysis; **$p < 0.01$ by multiple linear regression analysis; ***$p < 0.001$ by multiple linear regression analysis
CI: confidence interval; OHA: oral hypoglycemic agent; DM: diabetes mellitus

by 0.248 times (95% CI: 0.084–0.734) ($p < 0.05$). On the other hand, performance of low- and high-intensity aerobic exercise at the same time did not have a significant effect. Subjects who combined moderate- and high-intensity aerobic exercises and those who combined low-, moderate-, and high-intensity aerobic exercises were excluded from the analysis because their sample sizes were too small.

Moderate aerobic exercise is recommended by the ADA. In this study, we also found that doing one type of moderate aerobic exercise lowered the risk of glycemic control failure by 0.317 times (95% CI: 0.103–0.982). Sigal et al.[31] reported that a single performance of aerobic exercise and resistance exercise would improve glycemic control in patients with type 2 diabetes, with combined exercise providing the great-

est improvement. The discrepancy between our results and those reported by Sigal et al. might be due to the fact that our total exercise period of combined exercises was longer than that of the combined aerobic and resistance exercises. In addition, our study was not a blinded experiment. The results reported by Snowling and Hopkins[26] would be difficult to generalize because the studies included in their meta-analysis involved those with a small number of subjects[32] or those in which subjects were limited to only females[33], only males[34], or only the elderly[35].

In our study, if a subject was taking an oral hypoglycemic agent, the risk of glycemic control failure was increased by 2.636 times because hypoglycemic medicine cannot be prescribed for all patients just who are poorly controlled type

2 diabetes. The risk of glycemic control failure in subjects with hypertension was 2.440 times higher.

Hypertension is a common chronic disease that is present in at least 60% of patients with type 2 diabetes. When a person has both hypertension and type 2 diabetes, the risk of vascular complications is increased by 66 to 100% as compared with those with only one of these conditions[36]. Patients should have paid more attention to their health when they have more than one chronic disease.

In the present study, a 1 year increase in the duration of diabetes resulted in the risk of glycemic control failure increasing by 1.047 times (95% CI: 1.014–1.081), and a 1-cm increase in the waist circumference resulted in the risk of glycemic control failure increasing by 1.027 times (95% CI: 1.006–1.049). It is well known that obesity increases the occurrence of type 2 diabetes as well as the risk of complications[3].

This study had several limitations. First, it was a cross-sectional study, so it may be difficult to explain causal relationships. In particular, patients with diabetes are likely to change their exercise behavior based on their doctors' recommendations. Thus, the finding of a relationship between physical activity and diabetic control status was more evident than that exercise reduces the risk of glycemic control failure. However, in our view, this study was significant in that it examined the effect on glycemic control of combined aerobic exercises at different intensities. Second, we did not investigate the effects of exercise supervised by individual specialists, even though empirical evidence was found in the statistical data based on the extensive national sample representing Koreans that physical activity could alter diabetic control status. Therefore, further studies will be needed to overcome the limitations of this study and to determine the apparent causal relationship between physical activity and glycemic control.

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