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The Analysis of the Effects of Physical Activity on Impaired Fasting Glucose in Adults Over 20 Years of Age

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Abstract

Purpose : The purpose of this study was to investigate the effects of physical activity on impaired fasting glucose in adults aged 20 years or older.

Methods : This study utilized raw data from the 8th National Health and Nutrition Examination survey (2019~2021). The subjects of this study were 5,344 adults aged 20 years or older who were confirmed to be free of diabetes. The control variables in this study model are health behavior characteristics (subjective health status, smoking, drinking), anthropometric characteristics (body mass index), and personal background characteristics (gender, age, income level, education level, marital status). As for the analysis method, the degree of physical activity was made into a dummy variable, and a probit model was used.

Results : As a result of this study, compared to quartile 1 of the relative grip strength value obtained by dividing the grip strength by the body mass index (body mass index, ㎏, ㎡), fasting blood glucose levels were significantly higher in quartile 2 (.05, $p<.01$), quartile 3 (.04, $p<.01$), and quartile 4 (.04, $p<.01$). It was found that the probability of belonging to the normal category was higher than that of impaired fasting glucose. In addition, in the group of adults aged 20 or older who had a lot of aerobic and anaerobic physical activity, fasting blood sugar was more likely to be in the normal category.

Conclusion : Based on the results of this study, it was suggested that diabetes should be managed through physical activity in the pre-diabetic stage, as prevention is important as well as treatment. From a practical point of view, muscle strength, such as grip strength, can be identified as a reliable indicator for identifying impaired fasting glucose.

Key Words : diabetes mellitus, glucose, grip strength, impaired fasting, physical activity

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Ⅰ. Introduction

1. Research background and needs

Diabetes mellitus is a metabolic disease that creates many social and economic problems by causing complications, such as cardiovascular disease, chronic kidney disease, and diabetic retinopathy. Diabetes is a disease in which prevention and treatment are important, and interest in the pre-diabetes stage is increasing (Gregg et al., 2016). Pre-diabetes is classified into impaired fasting glucose and impaired glucose tolerance. Impaired fasting glucose means that the blood glucose level measured after fasting for 8 hours is lower than the diagnostic criteria for diabetes but higher than normal (100 to 125 ㎎/㎗).

The prevalence of diabetes in Koreans aged 30 years or older is increasing over time, with 13% in 2018, 14% in 2019, and 16% in 2020 (Kim, 2021). As of 2020, 1 out of 6 Korean adults over the age of 30 (16%) suffers from diabetes. When only fasting blood glucose was used for diagnosis, the prevalence of diabetes was 14%, with 1 out of 7 patients having diabetes. 3% of adults over the age of 65 were found to be diabetic.

Koreans' diabetes problem is in the pre-diabetes stage, which is very likely to progress to diabetes in the future. This means that the population with fasting glucose disorder, which is a high-risk group, is 24% (about 6.6 million people) of adults over the age of 30. In Korea, if diabetes and pre-diabetes are combined, one out of three adults over the age of 30 (about 10 million people) belongs to the high-risk group for diabetes or potential diabetes. Even if the current prevalence of diabetes is applied to the year 2050 without considering the situation in which the potential diabetic population progresses to diabetes, the number of diabetic patients will increase to 5.91 million, about twice the current number.

The cause of the increase in diabetic patients in Korea has not yet been clearly identified. In many studies, it is difficult to clarify the cause of the increase in the number of diabetic patients in Korea because the disease itself has multiple etiological triggers (Hur, 2021). However, it is argued that one of the biggest causes is the increase in obesity due to westernised lifestyles (Bae et al., 2022). The basis for this claim is that it is caused by an increase in insulin secretion among Asians (Jung et al., 2021). If you are obese, your blood sugar rises when you fail to keep up with it, which eventually leads to diabetes (Kim et al., 2021b). Accordingly, many studies claim that active intervention to improve the lifestyle of pre-diabetic patients is necessary (Hur et al., 2021). This is because physical activities, such as walking and light running, lower blood sugar. This is because it has the effect of increasing susceptibility (Lee & Shin, 2021).

More specifically, the average body mass index (BMI, ㎏, ㎡) of diabetic patients in Korea was 23 in the past, which was in the normal category, but recently exceeded 25, which was in the obesity category. The average body mass index was 25 (Kim et al., 2021a). This means that 3/4th of all diabetic patients in Korea are overweight or obese. Meanwhile, the average waist circumference of diabetic patients is 88 ㎝ for men and 86 ㎝ for women, and the rate of abdominal obesity (more than 90 ㎝ for men and 85 ㎝ for women) among adults in Korea is 41% for men and 56% for women (Lee et al., 2022).

This increase in diabetes ultimately leads to an increase in the medical expenses associated with diabetes. This is not just an individual burden, it eventually becomes a national burden. Moreover, if diabetes is poorly managed, medical expenses will increase due to an increase in the occurrence of chronic complications due to diabetes. In fact, diabetes is a major cause of all chronic diseases and complications, and is known to cost the most in each disease category (Kim & Jacobson, 2022). In other words, if the occurrence of diabetes is prevented and managed well, the occurrence of chronic diseases and complications can be reduced, thereby reducing individual and national medical expenses and improving quality of life.

For diabetic patients, it is generally known that blood sugar control needs to be managed, but to prevent chronic complications, blood pressure and cholesterol (lipid) levels must be well managed at appropriate levels (Rhee, 2022). As for disease management, it is understood that young diabetic patients in their 30s and 40s are more negligent in disease management (Jung et al., 2022). 22% of patients in their 30s and 19% in their 40s reached their blood sugar control goals, while 25% in their 60s and 33% in their 70s or older. In particular, the blood sugar and blood pressure control rates of men in their 30s were 1% and 46%, respectively, which were below average (Choi et al., 2022). This is a very big problem for national diabetes management, and it is why preventive management of young diabetic patients should be done well since the probability of complications increases as diabetes grows. Therefore, intensive preventive management in young diabetic patients is the most necessary aspect to reduce the occurrence of chronic complications after middle age. However, considering that the lack of comprehensive management of young male diabetic patients busy with work life will lead to a national burden due to rising social medical expenses in the next 20 years, prior education and management of these patients can be considered urgent.

Nevertheless, although many studies have been conducted on the association between physical activity and various chronic diseases, studies on its association with impaired fasting glucose are insignificant. In the results of this study, the association was different depending on the country and population group (Sun et al., 2022). Considering the high morbidity rate of progression from impaired fasting glucose to diabetes, various studies on factors related to impaired fasting glucose are needed. This study aims to examine the association between physical activity and impaired fasting glucose in Korean adults over the age of 20 based on data from the 2021 National Health and Nutrition Examination survey.

2. Research purpose

The purpose of this study was to analyze the influencing factors on impaired fasting glucose in adults aged 20 years or older. To this end, the following research questions were set.

First, what is the relationship between grip strength and impaired fasting glucose?

Second, what is the relationship between health behavior characteristics(subjective health status, smoking, drinking) and fasting glucose disorder?

Third, what is the relationship between anthropometric characteristics (body mass index) and impaired fasting glucose?

Fourth, what is the relationship between individual characteristics and background factors (gender, age, income level, education level, marital status) and fasting glucose disorder?

Ⅱ. Methods

1. Subject

This study is a secondary data analysis study that utilizes raw data from the 8th National Health and Nutrition Examination Survey (2019~2021) and transforms and analyzes it according to the purpose of this study. This study was conducted with the approval of the Research Ethics Review Committee of the Korea Center for Disease Control and Prevention (Approval number 117002). Additionally, in order to examine the effect of physical activity on fasting blood sugar disorder, the subjects of this study were those who responded to all questions available for analysis, such as health behavior, body characteristics, socioeconomic background factors, and diabetes mellitus. The subjects were 5,344 adults aged 20 years or older who were confirmed to have no epilepsy. Looking at the variable descriptions and basic statistics of the final analysis target, Tables 1 and 2 are shown below:

Table 1. Basic statistics to be analyzed

Division	Number of cases (n)		Ratio (%)	Sum
Research target	Male	2502	46.82	5344 (100.00 %)
	Female	2842	53.18	

The dependent variable in this study was impaired fasting glucose, which corresponds to a fasting blood glucose level of more than 10 mg, dℓ and less than 126 mg, dℓ according to the criteria of the National Health and Nutrition Examination Survey (Korean Diabetes Association, 2021). The main independent variable was grip strength, and this value was used as the relative grip strength value divided by the body mass index (kg, m^2) (Lawman et al., 2016). The grip strength was divided into quartile 1, quartile 2, quartile 3, and quartile 4 and analyzed (Li et al., 2018). The physical activity variables were analyzed by dividing the number of walking days per week by the number of days of strength exercise per week. The number of walking days per week and the number of days of strength exercise per week are categorical data. Control variables in this study include health behavior characteristics (subjective health status, smoking, drinking), anthropometric characteristics (body mass index), and personal background characteristics (gender, age, income level, education level, and marital status).

Table 2. Variable explanation and basic statistics

Factor	Variable name	Variable description	Code	Mean±SD
Dependent variable				
Dependent variable	Fasting blood glucose disorder	Over 10 mg, dℓ, less than 126 mg, dℓ	1=abnormal (obstacle), 2=normal	1.23±.44
Independent variables				
Center independent variable 1	Hand grip strength	Hand grip strength/BMI ratio	1=quartile 1/ 2=quartile 2/ 3=quartile 3/ 4=quartile 4	2.50±1.12
Center independent variable 2	Physical activity	Walking days per week	1=less 2=more	1.34±.47
		Number of strength exercise per week	1=less 2=more	1.11±.31
Control variables				
Characteristics of health behavior	Subjective health status	Subjective health status classification	1=bad /2=average 3=good	2.02±.68
	Smoking	Smoking classification	1=currently smoking 2=past smoking 3=non smoking	2.36±.79
	Drinking	Drinking classification	1=low risk drinking 2=high risk drinking	1.25±.43
Characteristics of anthropometric factors	Body mass index	Obesity definition if you have a body mass index of 25 kg, m^2 or more	1=normal 2=obesity	1.34±.47

Table 2. Variable explanation and basic statistics (continued)

Factor	Variable name	Variable description	Code	Mean±SD
Personal characteristics background factors	Sex	Sex classification	1=male/2=female	1.53±.50
	Age	Age classification	1=20 to 40 years old 2=40 to 60 years old 3=over 60 years old	2.05±.79
	Income level	Household gross income quartile classification	1=1 quartile 2=2 quartile 3=3 quartile 4=4 quartile	2.73±1.07
	Education level	Classification of education level	1=middle school graduate /2=high school graduate / 3=college graduate	2.14±.80
	Marital status	Marriage status classification	1=single /2=married	1.31±.46

2. Research model

Based on the theoretical background and previous studies on the effects of physical activity on impaired fasting glucose, this study was constructed by including significant variables that were proven to have an effect on impaired fasting glucose. Table 3 summarizes the hypothesis and research model of this study.

Table 3. Hypothesis and research model

Hypothesis	Physical activity will have an effect on impaired fasting glucose
	· Grip strength · Physical activity background factors · Health behavior background factors · Physical characteristics background factors · Socioeconomic background factors → Disordered fasting blood sugar
Research model	$\triangle V_i = f(\psi_i, X_{ui}, P_{ui}) - f(X_{ni}, P_{ni}) = X_i\beta_i + \epsilon_i$
	$P(U_i = 1) = P(\triangle V_i > 0) = P(\epsilon_1 > X_i\beta_i) = \phi(X_i\beta_i)$ $P(U_i = 0) = P(\triangle V_i \le 0) = P(\epsilon_1 \le X_i\beta_i) = 1 - \phi(X_i\beta_i)$

3. Analysis method

Based on the theoretical background and previous studies on the effects of physical activity on impaired fasting glucose, the model of this study was constructed by including significant variables that were proven to influence impaired fasting glucose. The main independent variable in this study is physical activity, which is the choice behavior that appears according to the individual's will. A rationally-behaving individual acts according to the values of choices and personal preferences. As a model for analyzing these individual rational behaviors, the degree of physical activity was made into a dummy variable and empirically estimated using a probit model.

Impaired fasting glucose, the dependent variable of this study, is a categorical variable represented by a dichotomous response of 'normal' and 'abnormal'. For categorical variables, the distribution of errors is also discrete, so it is difficult to assume a normal distribution. Since the conditional variances of the error terms are not equal, the homoscedasticity assumption is violated, so there is a limit to the application of linear regression analysis. In addition, when linear regression analysis is applied and the dependent variable is a two-way response, the predicted value may be greater than 1 or less than 0, and the effect size of the explanatory variable may be estimated to be excessively low (Wooldridge, 2009). When a binary response is of interest, linear regression analysis is not an appropriate statistical analysis method (Kim & Park, 2014).

The probit model is generally used to statistically estimate the influence between a categorical dependent variable and an explanatory variable, so it can overcome the utility and standard problems of OLS when estimating a model with a dichotomous dependent variable. The probit model can estimate the marginal effect, which can compare the absolute effects of each explanatory variable compared to logistic regression analysis. In this study, we attempted to overcome the limitations of logistic regression analysis with a probit model. The coefficient value estimated using the probit model is not an absolute value but a value obtained by dividing the standard deviation of the unknown residual term by the original coefficient to be estimated.

Therefore, it is not appropriate to perform an analysis with the absolute value of the coefficient value estimated from the probit model. This is because only the significance and sign of the coefficient values estimated in the probit model are meaningful information. However, a relative comparison of the estimated coefficient values is possible. Due to the characteristics of the estimated coefficient values of the probit model, in the analysis using the probit model, it is possible to estimate the marginal effect that can compare the absolute effects of each explanatory variable. Accordingly, this study investigated the effect of physical activity on impaired fasting glucose using a probit model.

Ⅲ. Results

This study empirically identified the relationship between the effects of grip strength and physical activity on impaired fasting blood glucose, thereby providing important implications for value judgments about the choice of grip strength and physical activity, depending on individual will. In order to more elaborately carry out the results of this study, health behavior characteristic factors (subjective health status, smoking, drinking), body measurement characteristic factors (body mass index), and individual background factors (gender, age, income level, education level, marital status) were controlled, and their influence relationship was identified. The results of this study on this are presented in Table 4.

First,the variables that have a significant effect on the effect on grip strength and impaired fasting blood glucose were examined in detail. kg/m^2 compared to quartile 1, quartile 2 (.05, p<.01), quartile 3 (.04, p<.01), and quartile 4 (.04, p<.01) compared to fasting glucose disorders. It was found to have a statistically significant effect on the probability of blood sugar belonging to the normal category.

When controlling and examining the health behavior characteristics (subjective health status, smoking, drinking) in the relationship between grip strength and fasting glucose disorder, which is the second model, compared to quartile 1, the grip strength in quartile 2 (.06, p<.01), quartile 3 (.07, p<.01), and quartile 4 (.10, p<.01) showed a statistically significant effect on the probability of fasting blood sugar belonging to the normal category compared to impaired fasting glucose.

After examining the effects of subjective health status, smoking, and drinking, on fasting glucose disorder, the results showed that the perception of subjective health status as good compared to poor (.01, p<.05) was associated with impaired fasting glucose. In contrast, it was found that fasting blood glucose had a statistically significant effect on the probability of belonging to the normal category. In the case of smoking, compared to current smoking, past smoking (.04, p<.05), and non-smoking (.07, p<.01), fasting blood sugar is more likely to be in the normal category than non-smoking (.07, p<.01). was found to have a statistically significant effect.

Among health behavior factors, drinking had a statistically significant effect on the fact that high-risk drinking (-.07, p<.01) was more likely to be included in impaired fasting glucose compared to the probability that fasting blood sugar was in the normal category, compared to low-risk drinking.

In the third model, the relationship between grip strength and fasting glucose disorder when controlling and examining the health behaviors (subjective health status, smoking, drinking) and body measurement characteristics (body mass index), grip strength was higher than that of quartile 1. quartile 2 (.04, p<.01), quartile 3 (.06, p<.01), and quartile 4 (.07, p<.01). This showed a statistically significant effect that fasting blood glucose was more likely to be in the normal category compared to impaired fasting glucose.

After examining the effects of subjective health status, smoking, and drinking on fasting glucose disorder, the results showed that the perception of subjective health status as good compared to poor (.01, p<.05) was associated with impaired fasting glucose. In contrast, it was found that fasting blood glucose had a statistically significant effect on the probability of belonging to the normal category. In the case of smoking, compared to current smoking, past smoking (.04, p<.05), non-smoking (.05, p<.01), fasting blood sugar is more likely to be in the normal category than non-smoking (.05, p<.01). was found to have a statistically significant effect.

Among health behavior factors, drinking had a statistically significant effect due to the fact that high-risk drinking (-.06, p<.01) was more likely to be included in impaired fasting glucose compared to the probability of fasting blood sugar belonging to the normal category, compared to low-risk drinking. Additionally, compared to the case of normal body mass index, which is an anthropometric characteristic, obesity (-.16, p<.01) has a statistically significant effect due to the fact that the probability of being included in impaired fasting blood sugar is higher than the probability of fasting blood sugar belonging to the normal category.

In the fourth model, the relationship between grip strength and fasting blood glucose disorder, health behavior characteristics factors (subjective health status, smoking, drinking), body measurement characteristics factors (body mass index), and personal characteristics background factors (gender, age, income level, education level, marital status), compared to quartile 1, the degree of grip strength was quartile 2 (.02, p<.05), quartile 3 (.04, p<.01), and quartile 4 (.05, p<.01), respectively. It was found to have a statistically significant effect on the probability of fasting blood glucose belonging to the normal category compared to the disorder.

After examining the effects of subjective health status, smoking, and drinking, which are health behavior characteristic factors, on fasting glucose disorder, the perception of subjective health status as good compared to poor (.02, p<.05) was associated with impaired fasting glucose. In contrast, it was found that fasting blood glucose had a statistically significant effect on the probability of belonging to the normal category. In the case of smoking, compared to current smoking, past smoking (.01, p<0.05), and non-smoking (.02, p<0.01), fasting blood glucose is more likely to be in the normal category than non-smoking (.02, p<.01). was found to have a statistically significant effect on health behavior factors. Drinking had a statistically significant effect on the fact that high-risk drinking (-.06, p<.01) was more likely to be included in

Table 4. Probit model results of grip strength (hand grip strength, BMI ratio) on fasting blood glucose disorder

Factor	Variable name		Model 1	Model 2	Model 3	Model 4
	Intercept		1.70 (147.11)***	1.64 (73.17)***	1.88 (63.40)***	1.87 (32.82)***
Center ind. variable 1	Hand grip strength, BMI ratio*	Quartile 2	.05 (3.18)***	.06 (3.75)***	.04 (2.45)***	.02 (1.16)**
		Quartile 3	.04 (2.26)**	.07 (4.25)***	.06 (3.22)***	.04 (2.08)***
		Quartile 4	.04 (2.35)***	.10 (5.30)***	.07 (3.53)***	.05 (2.23)***
Characteristics of health behavior	Subjective health status**	Average		.04 (2.44)	.04 (1.98)	.00 (-.12)
		Good		.01 (.66)**	.01 (.35)**	.02 (1.08)**
	Smoking ***	Past smoking		.04 (2.15)**	.04 (2.19)**	.01 (.38)**
		Non smoking		.07 (4.18)**	.05 (2.97)***	.02 (1.25)***
	Drinking ****	High risk drinking		-.07 (-4.88)***	-.06 (-4.48)***	-.06 (-4.28)***
Characteristics of anthropometric factors	Body mass index *****	Obesity			-.16 (-12.29)***	-.14 (-11.27)***
Personal characteristics back ground factors	Sex^{+}	Female				.07 (3.59)***
	Age^{++}	40~60				-.13 (-8.46)***
		Over 60				-.22 (-11.09)***
	Income level^{+++}	Quartile 1				.01 (.13)
		Quartile 2				.01 (.11)
		Quartile 3				.01 (.74)*
	Education level^{++++}	High school graduate				.00 (.15)
		College graduate				.02 (.90)**
	Marital status^{+++++}	Arried				.03 (2.23)**

*p<.1, **p<.05, ***p<.01, *Reference variable on hand grip strength/BMI satio; quartile 1(.190868<=quartile 1<=.839474), quartile 2(.839475<=quartile 2<=1.102162), quartile 3(1.102163<=quartile 3<=1.43228), quartile 4(1.43229<=quartile 4<=2.670335), **Reference variable on subjective health status; 1=Bad, ***Reference variable on smoking; 1=currently smoking, ****Reference variable on drinking; 1=low risk drinking, *****Reference variable on body mass index; 1=normal, $^{+}$Reference variable on sex; 1=male, $^{++}$Reference variable on age; 1=20 to 40 years old, $^{+++}$Reference variable on income level; 1=1 quartile, $^{++++}$Reference variable on education level; 1=middle school, $^{+++++}$Reference variable on marital status; 1=single

impaired fasting glucose compared to the probability of fasting blood sugar belonging to the normal category, compared to low-risk drinking.

It was found to have a statistically significant effect on the probability of being included in impaired fasting glucose compared to the probability of fasting blood glucose belonging to the normal category in the case of obesity (-.14, p<.01) compared to the case of normal body mass index, which is a physiometric characteristic factor. appear.

In the case of gender, which is a factor of individual characteristics, it was found to have a statistically significant effect on the fact that the probability of fasting blood sugar belonging to the normal category was higher in the case of females (.07, p<.01) compared to males (.07, p<.01). Probability of fasting blood sugar falling within the normal category for those aged 40-60 years old (-.13, p<.01) and over 60 years old (-.22, p<.01) compared to those aged 20-40 years old Compared to , it was found to have a statistically significant effect on the probability of being included in fasting glucose disorder. For income level, 'high' (.01, p<.1) compared to 'low' had a statistically significant effect on the probability that fasting blood glucose belonged to the normal category compared to impaired fasting blood glucose. Education level was found to have a statistically significant effect on the probability that fasting blood sugar was in the normal category compared to those with a high school diploma or higher (.02, p<.1) compared to those with a middle or lower education. Marital status was found to have a statistically significant effect on the probability that fasting blood glucose belonged to the normal category compared to married (.03, p<.05) compared to single versus unmarried.

The results of physical activity on fasting blood glucose disorder are presented in Table 5. Looking specifically at the variables that have a significant effect on the effects of physical activity and impaired fasting glucose, the relationship between the degree of physical activity and impaired fasting glucose, the number of walking days per week is among the sub-items of physical activity. The degree of strength training (.01, p<.05) and the number of days of strength training per week (.01, p<.05) had a statistically significant effect on the probability of fasting blood sugar belonging to the normal category compared to impaired fasting glucose.

When controlling and examining the health behavior characteristics (subjective health status, smoking, drinking) in the relationship between the degree of physical activity and impaired fasting glucose, the number of walking days per week is among the sub-items of physical activity (.02, p<.05) and the number of strength training days per week (.02, p<.05) were found to have a statistically significant effect on the probability that fasting blood glucose belongs to the normal category compared to impaired fasting glucose.

After examining the effects of subjective health status, smoking, and drinking on fasting glucose disorder, the results showed that the perception of subjective health status as good compared to poor (.02, p<.05) was associated with impaired fasting glucose. In contrast, it was found that fasting blood glucose had a statistically significant effect on the probability of belonging to the normal category. In the case of smoking, compared to current smoking, past smoking (.04, p<.05) and non-smoking (.04, p<.01), fasting blood glucose is more likely to be in the normal category than non-smoking (.04, p<.01). was found to have a statistically significant effect on among health behavior factors, drinking had a statistically significant effect on the fact that high-risk drinking (-.07, p<.01) was more likely to be included in impaired fasting glucose compared to the probability that fasting blood sugar was in the normal category, compared to low-risk drinking.

In the third model, the relationship between the degree of physical activity and impaired fasting glucose, the health behavior characteristics (subjective health status, smoking, drinking) and body measurement characteristics (Body mass index) were controlled and examined. The number of walking days (.02, p<.05) and the number of days of strength training per week (.03, p<.05) were statistically higher than low, indicating a higher probability of fasting blood sugar belonging to the normal category compared to impaired fasting glucose. It was found to have a significant effect. In addition, as a result of examining the effects of subjective health status, smoking, and drinking, which are health behavior characteristic factors, on fasting glucose disorder, the perception of subjective health status as good compared to poor (.01, p<.05) was associated with impaired fasting glucose. In contrast, it was found that fasting blood glucose had a statistically significant effect on the probability of belonging to the normal category.

In the case of smoking, compared to current smoking, past smoking (.04, $p<.05$) and non-smoking (.03, $p<.01$), fasting blood sugar is more likely to be in the normal category than non-smoking (.03, $p<.01$). Drinking had a statistically significant effect due to the fact that high-risk drinking (-.06, $p<.01$) was more likely to be included in impaired fasting glucose compared to the probability of fasting blood sugar belonging to the normal category, compared to low-risk drinking.

It was found to have a statistically significant effect on the probability of being included in impaired fasting glucose compared to the probability of belonging to the normal category in the case of obesity (-.16, $p<.01$) compared to the case of normal body mass index, which is a physiometric characteristic factor. appear.

In the fourth model, the relationship between the degree of physical activity and impaired fasting glucose, the health behavior characteristics factors (subjective health status, smoking, drinking), anthropometric characteristics factors (body mass index), and personal characteristics background factors (gender, age, income level, education level, marital status), the number of walking days per week (.03, $p<.05$) and the number of strength training days per week (.03, $p<.05$) were higher than low among the sub-items of physical activity. It was found to have a statistically significant effect on the probability of fasting blood glucose belonging to the normal category compared to impaired fasting blood glucose.

After examining the effects of subjective health status, smoking, and drinking, which are health behavior characteristics, on fasting glucose disorder, the results showed that the perception of subjective health status as good compared to poor (.01, $p<.05$) was associated with impaired fasting glucose. In contrast, it was found that fasting blood glucose had a statistically significant effect on the probability of belonging to the normal category. In the case of smoking, compared to current smoking, past smoking (.01, $p<.05$), non-smoking (.02, $p<.01$), fasting blood glucose is more likely to be in the normal category than non-smoking (.02, $p<.01$). was found to have a statistically significant effect on Among health behavior factors, drinking had a statistically significant effect on the fact that high-risk drinking (-.06, $p<.01$) was more likely to be included in impaired fasting glucose compared to the probability of fasting blood sugar belonging to the normal category, compared to low-risk drinking.

It was found to have a statistically significant effect on the probability of being included in impaired fasting glucose compared to the probability of belonging to the normal category in the case of obesity (-.15, $p<.01$) compared to the case of normal body mass index, which is an anthropometric characteristic factor. appear. Additionally, in the case of gender, which is an individual characteristic, it was found that women (.04, $p<.01$) had a statistically significant effect on the fact that the fasting blood glucose level was more likely to be in the normal category than men. Probability of fasting blood sugar in the normal category for those aged 40-60 years old (-.14, $p<.01$) and 60 years old or older (-.22, $p<.01$) compared to those aged 20-40 years old, it was found to have a statistically significant effect on the probability statistically significant effect on the probability of being included in fasting glucose disorder.

Having a high income (.02, $p<.1$) had a statistically significant effect on the probability that fasting blood sugar belonged to the normal category compared to impaired fasting blood glucose. Education level was found to have a statistically significant effect on the probability that fasting blood sugar was in the normal category for those with a high school diploma or higher (.02, $p<.1$) compared to those with a middle or lower education. Marital status was found to have a statistically significant effect on the probability that fasting blood glucose belonged to the normal category for comparing married (.03, $p<.05$) to unmarried patients.

Table 5. Probit model results of physical activity on fasting blood glucose disorder

Factor	Variable name		Model 1	Model 2	Model 3	Model 4
	Intercept		1.73 (226.16)***	1.71 (86.26)***	1.94 (73.06)***	1.95 (4.56)***
Center Ind. variable 2	Physical activity	Walking days per week*	.01 (.94)**	.02 (1.48)**	.02 (1.55)**	.03 (2.22)**
		Number of strength exercise perweek**	.02 (.36)**	.02 (.07)**	.03 (.08)**	.03 (.19)**
Characteristics of health behavior	Subjective health status***	Average		.07 (3.70)	.05 (2.88)	.00 (.26)
		Good		.02 (1.45)**	.01 (.90)**	.01 (.83)**
	Smoking ****	Past smoking		.04 (2.34)**	.04 (2.28)**	.01 (.30)**
		Non smoking		.04 (2.64)***	.03 (1.89)**	.02 (1.16)***
	Drinking *****	High risk drinking		-.07 (-4.69)***	-.06 (-4.33)***	-.06 (-4.26)***
Characteristics of anthropometric factors	Body mass index ******	Obesity			-.16 (-12.98)***	-.15 (-12.12)***
Personal characteristics back ground factors	Sex+	Female				.04 (2.85)***
	Age++	40-60				-.14 (-8.67)***
		Over 60				-.22 (-11.64)***
	Income level+++	2 quartile				.01 (.08)
		3 quartile				.01 (.06)
		4 quartile				.02 (.81)**
	Education level++++	High school graduate				.01 (.38)
		College graduate				.02 (1.13)**
	Marital status+++++	Married				.03 (2.20)**

*p<.1, **p<.05, ***p<.01, *Reference variable on walking days per week; 1=less, **Reference variable on number of strength exercise per week; 1=less, ***Reference variable on subjective health status; 1=bad, ****Reference variable on smoking; 1=currently smoking, *****Reference variable on drinking; 1=low risk drinking, ******Reference variable on body mass index; 1=normal, +Reference variable on sex; 1=male, ++Reference variable on age; 1=20 to 40 years old, +++Reference variable on income level; 1=1 quartile, ++++Reference variable on education level; 1=middle school, +++++Reference variable on marital status; 1=single

Ⅳ. Discussion

In this study, the group with strong grip strengths showed a relatively low rate of impaired fasting glucose compared to the group with weak grip strengths. These results are in line with the results of studies on the relationship between grip strength and fasting glucose disorder revealed in other countries. Churilla et al. (2020) reported the relationship between grip strength and impaired fasting glucose by race using data from the US Health and Nutrition Examination Survey (2011~2014). Looking at the results of the main study, the prediabetes prevalence rate among Caucasians was higher in the group with low grip strength, but there was no significant difference in the non-Caucasian population (Churilla et al., 2020). Regarding the different research results by race, it can be identified that minority populations in the United States have a higher risk of developing diabetes than white populations. In other words, the relationship between grip strength and fasting glucose disorder by race is relatively small.

However, Peterson et al. (2017) reported that in a study on the relationship between grip strength and impaired fasting glucose in 4,544 Chinese in the United States, the rate of impaired fasting glucose was high in the group with weak grip strength. Li et al. (2018) revealed that fasting glucose disorders were more common in both males and females with weak grip strength.

Kera et al. (2018) examined grip strength, muscle strength, gait ability, and balance decline in elderly diabetic or pre-diabetic adults residing in a Japanese community. They found that diabetes was associated not only with cardiovascular and cerebrovascular diseases, but also with physical and cognitive decline. Huang et al. (2013) reported an inverse J-shaped association between fasting glucose quartiles and muscle strength, revealing that impaired fasting glucose was related to weak muscle strength. In the normal weight group, the weaker the grip, the higher the rate of progression from normoglycemia to pre-diabetes. However, in the overweight group, there was no significant relationship between grip strength and prediabetes.

These results suggest that, in the overweight group, the muscle-to-fat ratio is imbalanced, so the effect of muscle on blood sugar control, which is explained by grip strength, is relatively small. As a result of this study, the association between grip strength and fasting blood glucose impairment was significant, but it is difficult to see if there is a difference between races in the relationship between grip strength and fasting blood glucose. Therefore, in future studies, large-scale studies involving various races will be needed to determine whether there are racial differences in the relationship between grip strength and impaired fasting glucose levels.

From a medical point of view, grip strength is closely related to muscle function and energy metabolism. The reason why fasting glucose disorder was lower in the group with high grip strength is that skeletal muscle interacts with the pancreas and is involved in insulin secretion (Stenholm et al., 2011). Furthermore, exercise provides the ability to change blood sugar appropriately (Khalafi et al., 2022). Muscles are involved in the metabolism of sugar and fat in the body (Zierath, 2002). As such, it is determined that appropriate physical activity has a close relationship with the ability of energy metabolism related to blood sugar and acts as a buffer against rapid changes in blood sugar.

The American Diabetes Association recommends 150 minutes of physical activity per week and 5–7% weight loss for pre-diabetic patients. It was reported that pre-diabetic patients could reduce the number of patients suffering from type 2 diabetes by 40–70% through such physical activity (Colberg, 2016). This study looked at physical activity by dividing it into aerobic and anaerobic exercises. In other words, the effect of physical activity on impaired fasting glucose was examined by dividing it into walking exercises and resistance exercises. This study found that the rate of impaired fasting glucose was small in both the group that did a lot of walking exercise and the group that did a lot of resistance exercise. Regular physical activity delays the progression of muscle weakness and sarcopenia (Pillard et al., 2011), and physical activity increases insulin sensitivity (Bird & Hawley, 2017).

However, this study could not specifically determine which part of physical activity had a positive effect on impaired fasting glucose. In this regard, previous studies have reported that aerobic exercise increases mitochondrial density and insulin sensitivity in muscles, increases cardiac output, and reduces the risk of type 1 and type 2 diabetes and cardiovascular disease (Sluik et al., 2012).

According to a recent position statement by the American College of Sports Medicine and the ADA, it is recommended that resistance exercise be used in blood sugar control. Increasing muscle mass not only has a positive effect on body composition but also helps reduce the risk factors of other cardiovascular diseases. The reason for this is that physical activity can lead to metabolic improvements by improving cardiorespiratory endurance. Additionally, according to the meta-study analysis by Snowling et al. (2006), when aerobic exercise and resistance exercise were performed together for a certain period of time (12 weeks), glycated hemoglobin decreased and insulin resistance improved. Other risk factors, such as improvement in hyperlipidemia, lowering of blood pressure, and changes in body composition, showed differences among the studies. However, the improvement in these metabolic indicators was more effective when the two exercises were performed together.

Muscular strength, another component of physical fitness, can be improved through resistance training. Resistance exercises induce muscle hypertrophy and change to a muscle type suitable for exercise, resulting in improvement of overall metabolism (Braith et al., 2005). The GLUT4 protein is involved in this, and Holten et al. reported that an increase in GLUT4 protein through resistance exercise resulted in an improvement in blood glucose (Holten et al., 2004). However, it is known that this increased effect disappears within a very short time, and the increase in GLUT 4 protein obtained with long-term exercise of more than 5 weeks also did not last for more than 40 hours (Host et al., 1998). As such, physical activity is judged to have the function of regulating fasting blood sugar regardless of its form. Pre-diabetic patients should be able to make physical activity a part of their lives to prevent fasting glucose disorders and diabetes.

This study was conducted using raw data from the 8th National Health and Nutrition Examination Survey (2019~2021) and has the following limitations. Since this study is cross-sectional, only the relevance of grip strength and physical activity to impaired fasting glucose can be confirmed, and it is difficult to ascertain a causal relationship. This study attempted to control various factors, such as health behavior characteristics, anthropometric characteristics, and personal background factors, in order to clarify the relationship between physical activity and fasting glucose disorder in adults aged 20 years or older, but considered that all confounding variables were corrected. Additionally, since the National Health Survey collected data using the self-report method, it is possible that respondents gave different responses depending on their judgment. Therefore, in future research, it is suggested that more precise research should be conducted by securing objective data to conduct longitudinal research.

Ⅴ. Conclusion

This study examined grip strength and physical activity among the influencing factors on impaired fasting glucose in adults aged 20 years or older. The results of this study showed that the rate of impaired fasting glucose was lower in the group with higher relative grip strength. In addition, in the group with a lot of aerobic and anaerobic physical activity in adults aged 20 years or older, the rate of impaired fasting glucose was low. Like other countries, this study was conducted on the factors affecting fasting glucose disorder, suggesting that diabetes is a disease for which prevention as well as treatment is important, and that it should be managed through physical activity in the pre-diabetic stage.

The significance of this study is that it was carried out and confirmed similarly to other countries for the influencing factors on impaired fasting glucose in adults. Additionally, it is significant in that it has been revealed that adults over 20 years of age can have sufficient effects only with normal strength exercise and physical activity, rather than special test equipment to manage fasting glucose disorder. The implication from a practical point of view is that muscle strength, such as grip strength, is a reliable index that can be easily measured in a healthcare environment, so it can be applied to identify impaired fasting glucose. Additionally, it was found that physical activity is an essential element for improving the lifestyle of pre-diabetic patients, and it can be easily applied by patients. Through this point, patients will be able to play a role as basic information that can be easily understood and applied to fasting glucose disorder. Above all, this study suggests that it is important for patients to prevent and manage fasting glucose disorders through measuring muscle strength, such as grip strength, and performing physical activities suitable for the patient.

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