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Relationship between dietary flavonoid intake and obesity among Korean adults

한국 성인의 플라보노이드 섭취와 비만 간의 연관성

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김 지 윤

Abstract

Relationship between dietary flavonoid intake and obesity among Korean adults

JIYOON KIM
Public Health Nutrition
The Graduate School of Public Health
Seoul National University

Obesity is one of the major causes of chronic diseases and its prevalence has increased over the last few decades. Flavonoids possess preventive activities against the development of chronic diseases such as cancer, type 2 diabetes mellitus, cardiovascular diseases, and obesity. The purpose of this study was to investigate the association between dietary flavonoid intake and the prevalence of obesity, based on data from the Korean Health and Nutrition Examination Survey 2008–2011. This cross-sectional study included 16,604 Korean adults (6,719 men and 9,885 women) who completed a health interview, a nutrition survey, and a health examination. The general characteristics and dietary intakes of the participants were obtained using a standardized questionnaire and a 24-h recall, respectively. Three anthropometric indices were used to assess obesity: body mass index (BMI), waist circumference (WC), and percent body fat (%BF). After adjusting for covariates, a higher total flavonoid intake was associated with a lower prevalence of obesity, as determined by %BF (highest vs. lowest tertile; odds ratio [OR]: 0.81, 95% confidence interval [CI]: 0.68–0.96, *P* for trend = 0.0105), and abdominal obesity as determined by WC (highest vs. lowest tertile; OR 0.67, 95% CI 0.53–0.85, *P* for trend = 0.0031), in women but not in men. In contrast, there was no association between total dietary flavonoid intake and obesity as determined by BMI in either men or women. Our results suggest that an increased intake of dietary flavonoid may decrease the risk of obesity in Korean adults.

Keywords: dietary flavonoid intake: obesity: body mass index (BMI): percent body fat: waist circumference

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I. INTRODUCTION

Obesity is a primary factor underlying the development of a variety of chronic diseases[1; 2; 3]. The World Health Organization (WHO) defines obesity as abnormal and excessive accumulation of body fat that leads to increased risks of various illnesses[4]. Over the last few decades, obesity rates of world population aged 15 years and over have increased[5]. According to the WHO, which reported the prevalence of obesity by country (based on body mass index; BMI), the global prevalence of obesity in women was 14.9% in 2014, while that in men was 10.8%[6]. However, this trend differs in Korea. According to BMI, the most commonly used obesity standard, the prevalence of obesity in Korean adult women was 26.0% in 2015, similar to the rate of 26.2% in 1998, while that of Korean adult men was 39.7% in 2015, which is a significant increase from the rate of 25.1% in 1998[7]. Waist circumference (WC), another indicator of obesity, showed increases in obesity of 11.0% and 1.0% in men and women, respectively, compared with rates in 1998[7]. Obesity is a result of a combination of various factors including genetic, cultural, environmental, and socioeconomic influences[8]. Thus, many epidemiological studies have examined the association between dietary intake and obesity[9; 10; 11].

Multiple studies have recently demonstrated an association between flavonoids and obesity[12; 13; 14]. Flavonoids represent the largest constituent of a group of plant-based polyphenolic compounds comprised mainly of anthocyanidins, flavanols, flavanones, flavonols, flavones, and isoflavones. Major flavonoid-rich food sources include vegetables, fruits, legumes, cocoa, and tea[15]. Flavonoids play a variety of roles in plants, animals, and bacteria. To plants, flavonoids have main functions to grow and develop them[16]. Flavonoids help fruits to attract pollinator so it is easy to make fruits disperse seeds to grow and develop them well and flowers have their own colour and aroma owing to flavonoids. Also, flavonoids function as anti-stress effector, ultraviolet filters, signal molecules, etc[17]. In terms of health benefits, previous studies have reported that flavonoids possess potential preventive effects on chronic diseases such as cancer, type 2 diabetes mellitus, and cardiovascular disease[18; 19; 20]. However, few studies have investigated the correlation between dietary flavonoid intake and obesity in Korea. Rapid economic growth has changed the dietary habits of Koreans from a traditional rice-based diet to a Western style diet[21; 22; 23], further increasing the risk of overweight. Western eating patterns are associated with an increase in intake of fat and cholesterol[22; 24].

Thus, the present study aimed to investigate the association between dietary flavonoid intake and the prevalence of obesity among Korean adults using representative anthropometric measurement data, including BMI, WC, and percent body fat (%BF), from the Korea National Health and Nutrition Examination Survey (KNHANES).

Ⅱ. SUBJECTS AND METHODS

1. Study design and population

The KNHANES, which is a cross-sectional and nationally representative survey conducted by the Korea Centers for Disease Control and Prevention (KCDC), has been performed periodically since 1998 to investigate the health and nutritional statuses of the Korean population. The KNHANES was approved by the Korean Government (approval number 11702). The KNHANES consists of a health interview, a health behaviour examination, and a nutrition survey. Data were obtained from units of regions and households selected using a multi-stage clustered probability sampling design based on gender, age, and geographic area[25; 26]. The data assessed in the present study were obtained from the fourth and fifth KNHANES (2008 - 2011), which evaluated BMI, WC, and %BF[27].

In total, 37,753 subjects were initially included from the database, and individuals who were younger than 19 years of age (n=9,376), who did not have a %BF (n=9,462), WC (n=80), or BMI measurement (n=11), or who did not report 24-hour dietary recall data (n=2,220) were excluded. Ultimately, a total of 16,604 subjects were eligible for this study. All procedures involving human subjects in this study were approved by the Institutional

Review Board at the Korea Centers for Disease Control and Prevention, (IRB no. E1501/001-002) and written informed consent was obtained from all participants.

2. Estimation of total dietary flavonoid intake

The present study utilized the flavonoid database of common Korean foods (KFDB)[28; 29] developed from a previous study, which was based on the Korean Functional Food Composition Table[30], the United States Department of Agriculture (USDA) database of flavonoid contents in selected foods[31; 32; 33], and the Phenol-Explorer database[34; 35; 36]. The coverage of the food database in this study included 53% (1,685 items of 3,193 items) of the commonly consumed foods in Korea. The common Korean foods were classified into 18 different groups according to the Korean Food Composition Table of 2006[37]. Of these groups, animal products such as meats and poultry, eggs, and fish and shellfish were excluded, and different groups of seasonings, prepared foods, and other items were also excluded. Thus, the flavonoid content of a total of 12 food groups was analysed.

The priority criteria of the updated version for the selection of flavonoid content values were as follows: 1) content values using the direct analytical method in the Korean functional food composition table, 2) content values in the latest version of the USDA flavonoid database or Phenol-Explorer database, and 3) median values in previous studies[38]. The database was linked to the 24-hour dietary recall data of the KNHANES to estimate the individual and total dietary flavonoid intakes of the subjects included in this study. The flavonoid content of each food was calculated by multiplying the flavonoid content (KFDB value, mg) of 100 g of each food product by intake; this value was then divided by 100 to express the value in units of mg. In addition, an individual's daily flavonoid intake was expressed as the sum of their flavonoid intake calculated from all of the foods that they reported consuming in the 24-hour recall. The daily total flavonoid intake refers to the sum of each participant's flavonoid intake[28]. The flavonoid components used in this study are as follows. A total of 31 flavonoid compounds were classified into seven subclasses, as described in a previous study, based on the KFDB: flavonols (quercetin, kaempferol, myricetin, and isorhamnetin), flavones (luteolin and apigenin), flavanones (eriodictyol, hesperetin, and naringenin), flavan-3-ols (catechin, epicatechin, epigallocatechin, theaflavin, theaflavin-3-gallate, theaflavin3′-gallate, theaflavin3,3′-digallate, and thearubigin), anthocyanidins (cyanidin, delphinidin, malvidin, pelargonidin, peonidin and petunidin), isoflavones (daidzein, genistein, and glycetin), and proanthocyanidins (dimers, trimers, 4–6monomers, 7–10monomers, and > 10monomers)[28].

3. Health examination and cut-off value for obesity diagnosis

Obesity was diagnosed using three different indices: BMI, WC, and %BF. BMI, which is defined as weight (kg)/height (m^2), is the most common method used to diagnose obesity. To assess abdominal obesity, a standardized tape measurement technique was used to determine WC. %BF was measured using a dual-energy X-ray absorptiometry method with the DISCOVERY-W fan-beam densitometer (Hologic, Inc.; Marlborough, MA, USA). The obesity criteria for each index in the present study were as follows: BMI ≥ 25 kg/m^2[39], WC ≥ 90 cm for men and ≥ 85 cm for women[40], and %BF > 25% for men and > 35% for women[41]. The indices of obesity, including obesity according to BMI, WC, and %BF, were used in line with previous studies[42; 43].

4. Covariates

Sociodemographic variables, including gender, current age, household income, and education level, and lifestyle factors, including physical activity, alcohol consumption, and current smoking statuses, were assessed by the health interview survey and they were used as covariates in the present analyses.

Education level was divided into two categories: 'high' (graduated high school or higher education) and 'none'. Household income was divided into 'high' (≥ 2,000,000 KRW per month) and 'not'. Physical activity was divided into two categories: 'active' (≥ 20 min of strenuous exercise ≥ 3 times per week, ≥ 30 min of moderate physical activity, or ≥ 30 min of walking ≥ 5 times per week) or 'inactive'[44]. Smoking status was determined by asking each subject whether he/she is a current smoker who has smoked five or more packs of cigarettes (100 cigarettes) in their lifetime. Alcohol consumption status was determined by asking each subject whether he/she drank one or more alcoholic drinks per month in the past year. In addition, the intakes of energy and fibre were included as covariates based on 24-hour dietary recall data[10; 45].

5. Statistical analysis

All statistical analyses were performed using Statistical Analysis System (SAS) software (version 9.4, SAS Institute; Cary, NC, USA). The KNHANES data were collected using a multi-stage clustered design, and thus, strata, cluster, and weight values were applied to all analyses to represent the Korean population. All categorical data were presented as percentages and continuous data were presented as means and standard errors. The distributions of variables and means and standard errors were calculated using the PROC SURVEYMEANS procedure.

The odds ratios (ORs) and 95% confidence intervals (95% CIs) according to tertile of total dietary flavonoid intake and subclasses were analysed using PROC SURVEYLOGISTIC. Values of $P < 0.05$ were considered to indicate statistical significance.

Ⅲ. RESULTS

The general characteristics of the study subjects according to tertile of total dietary flavonoid and subclass intake are presented in Table 1. There were 6,719 men and 9,885 women, and the subjects were divided by tertile of dietary flavonoid intake. Among the male participants, the average intake of total dietary flavonoids was 38.1 mg/day for the lowest tertile (T1) and 450.8 mg/day for the highest tertile (T3). In comparison, women in the lowest tertile (T1) had an average intake of 29.9 mg/day and those in the highest tertile (T3) had an intake of 461.5 mg/day, demonstrating a significant intergroup difference. After adjusting for age, mean BMI (P = 0.0009) and WC (P = 0.0331) were significantly greater in men in the highest tertile compared with those in the lowest tertile. Conversely, women in the highest tertile of flavonoid intake had a tendency towards a significantly lower %BF (P < 0.0001) than those in the lowest tertile. In terms of obesity prevalence, obesity according to BMI was significantly increased in men (P = 0.0022). In women, the group with the highest total flavonoid intake showed lower obesity prevalence using WC (P = 0.0024) and %BF (P = 0.0076). Subjects in the highest tertile (T3) smoked fewer cigarettes compared with those in the lowest tertile (T1). Also, levels of education and household income were higher in the highest tertile (T3) in both men and women (P < 0.0001).

Table 2 shows the adjusted ORs and 95% CIs for the prevalence of obesity according to BMI, WC, and %BF by the tertile of total dietary flavonoid intake and its subclasses. A higher total dietary flavonoid intake was associated with a lower prevalence of obesity according to WC and %BF in women (OR = 0.67, 95% CI = 0.53 - 0.85, P for trend = 0.0031; OR = 0.81, 95% CI= 0.68 - 0.96, *P* for trend = 0.0105, respectively) after multi-variable adjustment.

With respect to flavonoid subclasses, a higher intake of flavonols was associated with a lower risk of obesity according to WC in women (OR = 0.68, 95% CI = 0.55 - 0.86, *P* for trend = 0.0009). The prevalence of obesity according to WC in women was also significantly decreased among individuals with a high intake of flavanones (OR = 0.73, 95% CI = 0.59 - 0.91, *P* for trend = 0.0076), flavanols (OR = 0.74, 95% CI = 0.60 - 0.92, *P* for trend = 0.0116), or proanthocyanidines (OR = 0.66, 95% CI = 0.53 - 0.82, *P* for trend = 0.0002) compared with those with the lowest intake. When using %BF as an obesity indicator, no flavonoid subclasses were negatively associated with obesity after multi-variable adjustment.

Anthocyanidins were associated with an increased risk of obesity based on BMI in men (highest vs. lowest tertile: OR = 1.20, 95% CI = 1.03 - 1.41, *P* for trend = 0.0332), but were associated with a lower risk of obesity based on %BF (highest vs. lowest tertile: OR = 0.79, 95% CI = 0.66 - 0.95, *P* for trend = 0.0123).

The contributions of the various food groups to tertile of total dietary flavonoid intake are presented in Table 3. For males, the sequential highest contributors of dietary flavonoids were vegetables, beverages, grains, and fruits in the highest tertile, while those for males in the lowest tertile were vegetables, grains, beverages, and oils. In women in the highest tertile, the sequential largest contributors of dietary flavonoids were vegetables, fruits, grains, and beverages. The contribution of flavonoids of the grains food group was higher in the highest tertile compared with the lowest tertile (−6.4% in men, −8.0% in women), while that of the fruit group was higher in the lowest tertile compared with the highest tertile (+11.4% in men and +16.4% in women).

Table 1. General characteristics of the study subjects according to tertile of total dietary flavonoid and subclasses intake and gender

	Men				Women			
	T1 (n = 2239)	T2 (n = 2240)	T3 (n = 2240)	*P*-value*	T1 (n = 3295)	T2 (n = 3295)	T3 (n = 3295)	*P*-value*
Flavonoids (mg/day, range)								
Total flavonoids	38.1 ± 0.5	118.5 ± 0.8	450.8 ± 12.2	<0.0001	29.9 ± 0.4	113.4 ± 0.8	461.5 ± 16.3	<0.0001
	(0 - 71.0)	(71.0 - 184.1)	(184.2 - 7120.3)		(0 - 60.7)	(60.7 - 187.2)	(187.2 - 7382.0)	
Flavonols	6.7 ± 0.1	20.4 ± 0.1	72.3 ± 2.0	<0.0001	4.3 ± 0.1	13.8 ± 0.1	58.4 ± 1.8	<0.0001
	(0 - 12.8)	(12.8 - 29.5)	(29.5 -1697.4)		(0 - 8.6)	(8.6 - 20.5)	(20.5 - 1187.7)	
Flavones	0.2 ± 0.0	0.9 ± 0.0	3.2 ± 0.1	<0.0001	0.1 ± 0.0	0.6 ± 0.0	2.6 ± 0.1	<0.0001
	(0 - 0.5)	(0.5 - 1.5)	(1.5 - 31.7)		(0 - 0.3)	(0.3 - 1.0)	(1.0 - 131.8)	
Flavanones	0.0 ± 0.0	0.0 ± 0.0	20.5 ± 1.0	<0.0001	0.0 ± 0.0	0.0 ± 0.0	25.3 ± 0.9	<0.0001
	(0 - 0)	(0 - 0)	(0 - 511.7)		(0 - 0)	(0 - 0)	(0 - 698.5)	
Flavanols	0.1 ± 0.0	1.7 ± 0.0	54.1 ± 5.5	<0.0001	0.1 ± 0.0	2.5 ± 0.0	55.2 ± 4.9	<0.0001
	(0 - 0.4)	(0.4 - 5.2)	(5.2 - 6592.2)		(0 - 0.4)	(0.4 - 7.6)	(7.6 - 6592.0)	
Isoflavone	2.1 ± 0.1	13.2 ± 0.1	59.0 ± 1.6	<0.0001	0.9 ± 0.0	7.6 ± 0.1	39.8 ± 0.9	<0.0001

	(0 - 6.2)	(6.2 - 21.9)	(21.9 - 1069.1)		(0 - 3.0)	(3.0 - 13.7)	(13.8 - 1069.2)	
Anthocyanidins	1.7 ± 0.1	16.5 ± 0.2	124.0 ± 5.8	< 0.0001	1.6 ± 0.0	15.6 ± 0.2	139.4 ± 9.2	< 0.0001
	(0 - 6.6)	(6.7 - 30.5)	(30.5 - 2669.6)		(0 - 6.0)	(6.0 - 30.0)	(30.0 - 4268.4)	
Proanthocyanidins	0.0 ± 0.0	12.6 ± 0.2	196.1 ± 6.3	< 0.0001	0.3 ± 0.0	18.0 ± 0.3	217.7 ± 7.0	< 0.0001
	(0 - 0.6)	(0.6 - 34.5)	(34.5 - 3074.5)		(0 - 2.8)	(2.8 - 54.4)	(54.5 - 3760.9)	
Energy (kJ/day)	8366.5 ± 88.8	10404.0 ± 101.8	11178.0 ± 116.9	< 0.0001	5861.5 ± 47.0	6998.6 ± 62.2	7929.8 ± 70.7	< 0.0001
Fibre (g/day)	6.3 ± 0.1	8.0 ± 0.1	10.6 ± 0.2	< 0.0001	5.0 ± 0.1	6.5 ± 0.1	8.9 ± 0.2	< 0.0001
Age (yrs)	43.6 ± 0.5	42.8 ± 0.4	45.3 ± 0.4	< 0.0001	46.3 ± 0.5	45.8 ± 0.4	46.2 ± 0.3	0.6259
Obesity Index								
BMI (kg/m^2)	23.8 ± 0.1	24.0 ± 0.1	24.3 ± 0.1	0.0009	23.2 ± 0.1	23.2 ± 0.1	23.2 ± 0.1	0.8605
WC (cm)	83.6 ± 0.3	83.9 ± 0.3	84.5 ± 0.2	0.0331	78.0 ± 0.2	77.8 ± 0.2	77.6 ± 0.2	0.3939
%BF	22.0 ± 0.2	22.0 ± 0.2	22.0 ± 0.2	0.9807	33.2 ± 0.2	33.1 ± 0.1	32.5 ± 0.1	< 0.0001
Obesity prevalence (%)								
BMI (kg/m^2)⊙	33.0	36.2	39.2	0.0022	27.7	26.4	26.5	0.5312
WC (cm)†	23.4	25.3	25.8	0.2604	25.6	22.8	21.2	0.0024
%BF‡	30.3	29.2	27.8	0.3309	38.0	36.2	33.3	0.0076

Physical activity (%)[§]	25.2	26.7	29.5	0.0304	21.7	20.6	23.4	0.0900
Alcohol Consumption (%)[‖]	75.8	79.2	73.0	0.0004	40.8	42.5	38.6	0.0326
Current smoking (%)[¶]	50.6	47.9	38.9	< 0.0001	8.1	5.9	4.5	< 0.0001
High education level (%)[※]	72.2	78.8	79.3	< 0.0001	59.4	64.2	66.5	< 0.0001
High household income (%)[Ŧ]	21.3	29.6	33.9	< 0.0001	21.6	27.4	32.3	< 0.0001

Data are expressed as age-adjusted means ± standard errors or percentages. * *P*-values across tertiles of dietary total flavonoid intake were calculated using the general linear model for continuous variables and chi-square test for categorical variables. BMI: ≥ 25 kg/m^2. † Waist circumference: ≥ 90 cm for men and ≥ 85 cm for women. ‡ Percent body fat: > 25% for men and > 35% for women. § Number of subjects who performed ≥ 20 min of strenuous physical activity ≥ 3 times per week, ≥ 30 min of moderate physical activity ≥ 5 times per week, or ≥ 30 min of walking ≥ 5 times per week. ‖ Number of subjects who drank once or more per month during the past year. ¶ Number of subjects who smoke currently and have smoked five or more packs of cigarettes (100 cigarettes) in their lifetime. ※ Graduated high school or obtained higher education. Ŧ Household income per month: ≥ 2,000,000 KRW. BMI, body mass index; WC, waist circumference; %BF, percent body fat.

Table 2. Odds ratios and 95% confidence intervals of obesity according to tertile of total dietary flavonoid and subclasses intake by gender

	Men						Women					
	T1	T2		T3		*P* for trend	T1	T2		T3		*P* for trend
	OR	OR	95% CI	OR	95% CI		OR	OR	95% CI	OR	95% CI	
Total Flavonoids												
Obesity by BMI‡	1	1.08	(0.92, 1.26)	1.15	(0.97, 1.37)	0.1060	1	0.99	(0.86, 1.13)	1.03	(0.89, 1.18)	0.6476
Obesity by WC§	1	1.12	(0.87, 1.44)	0.80	(0.63, 1.03)	0.0125	1	0·76	(0.61, 0.95)	0.67	(0.53, 0.85)	0.0031
Obesity by %BF‖	1	1.00	(0.84, 1.20)	0.82	(0.67, 1.02)	0.0414	1	0.94	(0.79, 1.11)	0.81	(0.68, 0.96)	0.0105
Flavonols												
BMI	1	1.07	(0.92, 1.25)	1.13	(0.95, 1.35)	0.1588	1	0.99	(0.86, 1.14)	1.13	(0.98, 1.31)	0.0825
WC	1	0.88	(0.67, 1.15)	0.93	(0.71, 1.21)	0.4872	1	0.81	(0.65, 1.00)	0.68	(0.55, 0.86)	0.0009
%BF	1	0.92	(0.77, 1.11)	0.88	(0.71, 1.09)	0.2197	1	1.17	(1.00, 1.37)	0.94	(0.79, 1.12)	0.4404
Flavones												
BMI	1	1.03	(0.87, 1.20)	1.05	(0.91, 1.22)	0.5228	1	1.17	(1.02, 1.34)	1.17	(1.01, 1.35)	0.0333
WC	1	1.01	(0.77, 1.32)	0.89	(0.68, 1.16)	0.4546	1	0.96	(0.77, 1.19)	0.91	(0.72, 1.15)	0.4247
%BF	1	0.89	(0.74, 1.09)	0.88	(0.72, 1.09)	0.2134	1	0.99	(0.84, 1.16)	0.92	(0.77, 1.10)	0.3594

Flavanones												
BMI	1	1.04	(0.89, 1.22)	1.16	(0.99, 1.36)	0.0490	1	1.02	(0.89, 1.16)	1.01	(0.87, 1.16)	0.9934
WC	1	0.79	(0.62, 1.02)	0.83	(0.65, 1.05)	0.2359	1	0.85	(0.69, 1.04)	0.73	(0.59, 0.91)	0.0076
%BF	1	0.92	(0.75, 1.12)	0.95	(0.78, 1.16)	0.7432	1	1.04	(0.88, 1.22)	0.92	(0.78, 1.07)	0.1718
Flavanols												
BMI	1	0.98	(0.84, 1.14)	1.04	(0.89, 1.23)	0.4697	1	0.99	(0.87, 1.13)	1.01	(0.89, 1.15)	0.7853
WC	1	0.93	(0.72, 1.20)	0.98	(0.76, 1.26)	0.8987	1	0.87	(0.70, 1.08)	0.74	(0.60, 0.92)	0.0116
%BF	1	1.01	(0.84, 1.21)	0.92	(0.75, 1.13)	0.3553	1	1.05	(0.90, 1.23)	0.94	(0.80, 1.10)	0.1812
Isoflavone												
BMI	1	1.12	(0.97, 1.31)	1.01	(0.87, 1.16)	0.4256	1	1.03	(0.90, 1.17)	0.89	(0.76, 1.03)	0.3563
WC	1	0.95	(0.74, 1.22)	0.85	(0.67, 1.07)	0.2730	1	0.95	(0.77, 1.17)	0.84	(0.68, 1.05)	0.2050
%BF	1	1.08	(0.90, 1.29)	0.93	(0.78, 1.11)	0.8642	1	1.05	(0.89, 1.24)	0.97	(0.83, 1.14)	0.9835
Anthocyanidins												
BMI	1	1.15	(1.00, 1.33)	1.20	(1.03, 1.41)	0.0332	1	1.09	(0.95, 1.24)	1.01	(0.88, 1.16)	0.9025
WC	1	1.02	(0.79, 1.32)	1.00	(0.77, 1.29)	0.9446	1	0.92	(0.74, 1.14)	0.93	(0.74, 1.16)	0.6114
%BF	1	0.92	(0.77, 1.11)	0.79	(0.66, 0.95)	0.0123	1	1.00	(0.85, 1.18)	0.92	(0.77, 1.11)	0.3264

Proanthocyanidins												
BMI	1	1.02	(0.87, 1.20)	1.06	(0.90, 1.24)	0.4968	1	0.99	(0.87, 1.14)	1.02	(0.89, 1.17)	0.6722
WC	1	1.07	(0.83, 1.39)	0.86	(0.67, 1.10)	0.0765	1	0.86	(0.70, 1.05)	0.66	(0.53, 0.82)	0.0002
%BF	1	1.18	(0.97, 1.42)	0.86	(0.71, 1.04)	0.0048	1	0.98	(0.84, 1.14)	0.88	(0.75, 1.03)	0.0931

Data from a multivariate logistic regression analysis adjusting for age, BMI, alcohol consumption status, education level, energy intake, fibre intake, household income, physical activity, and smoking status. BMI: ≥ 25 kg/m^2. [§] Waist circumference: ≥ 90 cm for men and ≥ 85 cm for women. [‖] Percent body fat > 25% for men and > 35% for women. OR, odds ratio; CI, 95% confidence interval.

Table 3. Contribution to tertile of total dietary flavonoid intake in food groups

Contribution (%)	Men				Women			
	T1	T2	T3	*P*-value*	T1	T2	T3	*P*-value
Grains	20.6 ± 0.3	15.9 ± 0.2	14.2 ± 0.2	< 0.0001	23.1 ± 0.3	18.1 ± 0.2	15.1 ± 0.2	< 0.0001
Potatoes and Starch	0.8 ± 0.1	0.7 ± 0.0	0.7 ± 0.0	0.2652	1.1 ± 0.1	1.0 ± 0.1	1.0 ± 0.1	0.4978
Sweets	4.0 ± 0.1	4.3 ± 0.1	3.5 ± 0.1	0.0002	3.8 ± 0.1	3.8 ± 0.1	3.2 ± 0.1	0.0001
Legumes	2.3 ±0.1	3.5 ± 0.1	4.4 ± 0.2	< 0.0001	2.5 ±0.1	4.1 ± 0.1	4.4 ± 0.1	< 0.0001
Seeds and Nuts	0.4 ± 0.0	0.6 ± 0.0	0.7 ± 0.1	0.0050	0.5 ± 0.0	0.6 ± 0.0	0.7 ± 0.0	0.0012
Vegetables	34.5 ± 0.5	35.2 ± 0.4	32.7 ± 0.4	< 0.0001	35.2 ± 0.4	35.4 ± 0.4	31.3 ± 0.3	< 0.0001
Mushrooms	0.8 ±0.1	0.6 ± 0.1	0.7 ± 0.1	0.5484	0.8 ± 0.1	0.9 ± 0.1	0.9 ± 0.1	0.5597
Fruits	1.7 ± 0.1	4.2 ± 0.2	13.1 ± 0.4	< 0.0001	3.0 ± 0.2	8.5 ± 0.2	19.4 ± 0.4	< 0.0001
Seaweed	6.6 ± 0.3	5.4 ± 0.2	5.2 ± 0.2	< 0.0001	7.3 ± 0.3	6.4 ± 0.2	6.0 ± 0.2	0.0004
Milk and Dairy products	2.6 ± 0.2	2.0 ± 0.1	2.1 ± 0.2	0.0435	3.7 ± 0.2	2.8 ± 0.1	2.5 ± 0.1	< 0.0001
Oils	8.0 ± 0.2	9.0 ± 0.2	6.9 ± 0.2	< 0.0001	7.2 ± 0.2	7.4 ± 0.2	5.9 ± 0.1	< 0.0001
Beverages	17.8 ±0.5	18.7 ± 0.5	15.8 ± 0.4	< 0.0001	11.6 ±0.3	11.1 ± 0.3	9.5 ± 0.3	< 0.0001

Data are expressed as age-adjusted means ± standard errors. **P*-values were calculated using a general linear model.

Ⅳ. DISCUSSION

This is the first large-scale, cross-sectional study using data from the KNHANES that investigated the association between dietary flavonoid intake and obesity among a Korean population. We found that dietary flavonoid intake was significantly inversely associated with risk of obesity in Korean adults.

In the present study, a higher intake of total dietary flavonoids was associated with a lower prevalence of obesity according to %BF in women, which is similar to previously reported results[(46)]. Because the intakes of dietary flavonoid groups such as flavonols, flavan-3-ols, anthocyanins, and flavonoid polymers had an inverse association with weight change, Bertoia *et al.* found that higher consumption of foods rich in flavonoids may contribute to weight maintenance[(45)]. Some clinical studies have investigated the association between isoflavone intake and weight loss, but this relation has yet to be fully elucidated[(47; 48)].

In an age-adjusted model, a higher dietary total flavonoid intake was associated with a higher prevalence of obesity by BMI in Korean men but not in women. However, this trend was no longer significant after adjusting for covariates. We also found that anthocyanidins showed a significant association with the risk of obesity according to BMI in men.

Previous studies have reported that using BMI for obesity evaluation has limitations because of its lack of ability to discriminate fat mass from lean mass, or to identify visceral fat, which is relevant to metabolic diseases and cardiovascular risk. However, BMI-based obesity determination has been widely used and is convenient[49; 50]. Therefore, further studies are required to clarify the effects of dietary flavonoid intake on obesity according to BMI.

A higher intake of total dietary flavonoids was associated with a lower prevalence of obesity by WC in women but not men. This finding is similar to that of previous Korean study, which reported an inverse association between the intake of vitamin C and abdominal obesity by WC in women but not men[10]. Unhealthy habits, such as smoking or alcohol consumption, were significantly more likely to occur in men than women and may inhibit the beneficial effects of flavonoids on health, including antioxidant activities[51; 52]. The greater proportion of these lifestyle variables in men than in women might increase the level of oxidative stress and attenuate any antioxidant effects of the flavonoids. Therefore, future studies investigating the effects of covariates on the risk of obesity, especially in a multivariate-adjusted model, are warranted.

In addition, association between a higher intake of total dietary flavonoids and a lower prevalence of obesity according to WC and %BF only in women can be hypothesized about total dietary antioxidant capacity(TAC). TAC in antioxidants such as flavonoids can be different according to gender. According to Ham *et al.*, TAC in women was significantly high that in men[53]. This TAC difference between men and women may support results of the present study.

In our study, anthocyanidins showed a significant inverse association with obesity according to %BF in men, and proanthocyanidins showed an inverse association with abdominal obesity according to WC in women. Thus, our results indicated gender differences between flavonoid subclasses and the prevalence of obesity. Further additional studies are needed to explain the relation between flavonoids and their subclasses with obesity by gender among Koreans.

The present study has several limitations that should be noted. First, although data from a large-scale survey were examined, no causal associations could be determined between total dietary flavonoid intake and obesity, because the KNHANES is based on a cross-sectional study design. Next, we were unable to estimate the usual intake of the study subjects because the dietary survey used in the KNHANES was a dietary recall of only one day. Finally, the indices used are limited in their ability to precisely evaluate the extent of obesity[(50)]. Despite these limitations, our study is the first to confirm an association between dietary flavonoid intake and the prevalence of obesity using data from a nationally representative Korean adult population. In addition, BMI, WC, and %BF, which are used to define obesity, were analysed and compared according to gender.

In conclusion, this study indicated that a high intake of dietary flavonoids decreases the risk of obesity among women, especially based on WC and %BF. These results can be used to refine the dietary recommendations for weight maintenance in Korean populations. However, expanded flavonoid databases and further researches to support the present study are required.

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Ⅵ. KOREAN ABSTRACT

한국 성인의 플라보노이드 섭취와 비만 간의 연관성

김 지 윤

서울대학교 보건대학원

보건학과 보건영양학 전공

비만은 만성질환의 주요 원인 중 하나로, 그 유병률은 지난 수 십 년 동안 계속적으로 증가하여 왔다. 플라보노이드는 다수의 역학 연구를 통해 암, 제 2형 당뇨, 심혈관질환 및 비만 등의 만성 질환의 발전을 저해하는 예방적인 효능을 지니고 있는 것으로 알려져 있다. 본 연구의 목적은 한국 성인의 식이를 통한 플라보노이드 섭취 양상을 파악하고 비만 간의 상관성을 분석하여 비만 예방 및 관리를 위한 식사지침 기초자료를 마련코자 함이며, 분석의 근간의 되는 자료는 2008년부터 2011년까지의 국민건강영양조사자료를 바탕으로

하였다. 이 단면 연구는 검진조사, 건강설문조사, 그리고 영양조사를 완료한 총 16,604명의 성인 (남성 6,719명, 여성 9,885명)을 대상으로 하였다. 대상자의 일반적인 특성 및 식이 조사는 표준화된 질문 및 24시간 회상법을 각각 사용하였고, 비만을 측정하는 인체계측 지표로는 체질량지수, 허리둘레, 체지방률 세 가지가 사용되었다. 총 플라보노이드 섭취량이 높을수록 더 비만율이 낮은 것으로 나타났는데 (변수 보정 후), 여성의 체지방률 (오즈비: 0.81, 95% 신뢰구간: 0.68 - 0.96, P for trend = 0.0105)과 허리둘레(오즈비: 0.67, 95% 신뢰구간: 0.53 - 0.85, P for trend = 0.0031) 를 비만 척도로 사용하였을 때 그러한 경향이 뚜렷이 나타났으며, 남자에게서는 나타나지 않았다. 이와는 대조적으로, 체질량지수가 비만의 지표인 경우 총 플라보노이드 섭취량과 비만 간의 상관관계는 드러나지 않았다. 본 연구 결과는 식이 섭취를 통한 플라보노이드가 한국 성인 여성의 복부비만 및 체지방 축적의 위험을 낮추는 데 도움을 줄 수 있다는 것을 구명했다는 점에서 의미가 있으며, 현재 한국의 큰 보건학적 문제로 대두되고 있는 비만을 예방하는 영양정책 수립에 과학적인 근거로 다양하게 활용될 수 있을 것으로 기대되는 바이다.

주요어: 플라보노이드 섭취량: 비만: 체질량지수: 체지방률: 허리둘레

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