Association of Dietary Flavonoid Intake with Prevalence of Type 2 Diabetes Mellitus and Cardiovascular Disease Risk Factors in Korean Women Aged ≥30 Years

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(Received September 27, 2016)

Summary The purpose of this study was to investigate the association between dietary flavonoid intake and the prevalence of type 2 diabetes mellitus (T2DM) and cardiovascular disease (CVD) risk factors among Korean women aged ≥30 y. This study used data collected from the 2007–2012 Korean National Health and Nutrition Examination Survey. We excluded subjects who had energy intake < 500 kcal or ≥ 5,000 kcal, were diagnosed with chronic disease, were taking medication, or were pregnant or lactating. The final subjects included 7,963 women, and they were divided into 2 groups, the normal fasting glucose (NFG) group (n = 7,738) and the T2DM group (n = 225). The intake of flavonoids was estimated on the basis of the flavonoid database. After adjustment for confounding factors, the mean intakes of fruits, anthocyanidins, and flavones were significantly lower in the T2DM group than in the NFG group. In multiple regression analysis, the dietary flavonoid intake was negatively associated with systolic blood pressure, triglyceride, TG/HDL-cholesterol, and homeostatic model assessment of insulin resistance. Daily intake of flavones above the 25th percentile was associated with a lower prevalence of T2DM compared with intake below the 25th percentile (OR = 0.593, 95% confidence interval (CI): 0.414–0.847). These study results showed that dietary flavonoid intake may have some beneficial effects in reducing CVD risks and prevalence of T2DM in Korean women.

Key Words flavonoids, type 2 diabetes mellitus, cardiovascular disease, Korean women

Dietary flavonoids, abundant in fruits and vegetables, are a group of naturally occurring polyphenolic compounds (1). The major health benefits of flavonoids include their antioxidative (2), anti-inflammatory (3), and antiplatelet (4) properties, as well as their antihypertensive (5), and lipid-reducing (6) properties. Several studies have shown that dietary flavonoids are inversely associated with type 2 diabetes mellitus (T2DM) incidences (7, 8). Dietary flavonoids might also decrease cardiovascular disease (CVD) incidence or mortality (9–12) by reducing the baseline measures of several CVD risk factors such as blood pressure (13), total cholesterol (TC), and low density lipoprotein cholesterol (LDL-C) (14).

T2DM is one of the most common metabolic disorders across the globe (15). The consumption of dietary flavonoids has been shown to be associated with lower incidences of T2DM (7, 8). Abundant literature exists reporting that flavonoids decrease plasma glucose and improve insulin secretion and insulin resistance (HOMA-IR), factors which are implicated in the development of T2DM (16, 17). One of the main causes of morbidity and mortality observed among individuals with T2DM is CVD. DeSouza and Fonseca (18) identified increased blood pressure and triglyceride (TG) levels, and decreased high density lipoprotein cholesterol (HDL-C) as some of the factors that lead to CVD complications among T2DM patients. Thus, controlling these common risk factors is important in reducing CVD mortality among T2DM patients (19).

It is noteworthy that the association between diabetes and CVD has been suggested to be stronger in women than in men (20, 21). This observation might be because of increased susceptibility to unhealthy lipid profiles (22), higher inflammatory stress (23) and endothelial dysfunction (24) in women than men with diabetes. In spite of these studies, to our knowledge, there had been no study on the association between dietary flavonoid intake and the prevalence of T2DM and CVD risk factors in Korean women.

Therefore, this study aimed to examine the association between dietary flavonoid intake and the prevalence of T2DM, and CVD risk factors in T2DM patients and people with normal fasting glucose among Korean women aged ≥ 30 y from the Korean National Health and Nutrition Examination Survey (KNHANES).

MATERIALS AND METHODS

Study subjects. This study was based on data obtained from the KNHANES IV, conducted from 2007 to 2009, and the KNHANES V, conducted from 2010 to 2012.
The KNHANES studies are cross sectional and nationally representative surveys carried out by the Korea Centers for Disease Control and Prevention. A detailed description of the survey design and data collection in the KNHANES has been published elsewhere (25).

A total of 50,450 people aged ≥1 y participated in the KNHANES IV and KNHANES V. Among these participants, we excluded subjects who were males (n=29,226), females under 30 y (n=8,635), and pregnant or lactating women (n=388). Among the remaining 18,456 subjects, we excluded subjects who had a chronic disease (stroke, angina, myocardial infarction, current tuberculosis, chronic obstructive lung disease, renal failure, viral hepatitis carrier, liver cirrhosis or any malignancy) or type 1 diabetes mellitus (T1DM) (n=1,105), those who were taking estrogen or medication for hypertension, dyslipidemia, or diabetes mellitus (n=5,113), had an energy intake <500 kcal (n=8) or ≥5,000 kcal (n=123), or had missing data (n=2,725). Of the remaining 9,383 subjects, we also excluded subjects who had an impaired fasting glucose level (n=1,422) to investigate the difference between healthy people and T2DM patients. Therefore, a total of 7,963 subjects were eligible for this analysis.

The study subjects were divided into 2 groups as follows: the normal fasting glucose (NFG) group (n=7,738) and the T2DM group (n=225). The NFG was defined as a fasting plasma glucose level <100 mg/dL. Further, T2DM was defined as a fasting plasma glucose level ≥126 mg/dL along with the current usage of DM medication or a physician’s diagnosis of DM. In our study, we excluded medication users to eliminate the effects of medication on clinical data (blood pressure, lipid profiles, and glucose).

This study was approved by the Institutional Review Board of the Korea Centers for Disease Control and Prevention Institutional Review Board (Confirmation Number: 2007-02CON-04-P, 2008-04EXP-01-C, 2009-01CON-03-2C, 2010-02CON-21-C, 2011-02CON-06C, 2012-01EXP-01-2C).

General characteristics. The health interview survey included questions on age, sex, education, employment status, monthly household income, residential area, family history of diabetes, and health-related behaviors such as smoking habit, alcohol consumption, exercise and postmenopausal status. Education level was classified into 4 categories as elementary school or lower, middle school, high school and college or higher. Household income status was categorized according to quartiles of total income. Residential area was divided into 2 groups as urban and rural. Under health behavior, a current smoker was defined as someone who had smoked more than five packs of cigarettes throughout their lifetime and still smoked at the time of the survey. A regular drinker was defined as someone who currently drank and had consumed more than one glass of alcohol per month within the last year regardless of alcohol type. Regular exercise was limited to walking more than 5 times per week for more than 30 min at a time or participating in regular moderate exercise (more than 5 times per week for more than 30 min at a time) or strenuous exercise (more than 3 times per week for more than 20 min at a time) exercise.

Anthropometric and clinical characteristics. Anthropometric and clinical parameters were measured through the health examination survey. Height, weight, body mass index (BMI), waist circumference, systolic blood pressure (SBP), and diastolic blood pressure (DBP) were used for analysis in this study. BMI was calculated by dividing the weight of the participants by the square of their height (kg/m²). SBP and DBP were calculated as the average of two measurements, recorded at an interval of 5 min.

Blood samples from the subjects were collected after >8 h of fasting and were analyzed within 24 h. Fasting blood sugar (FBS), hemoglobin A1c (HbA1c), fasting insulin, TC, TG, and HDL-C were measured. Plasma concentrations of glucose and lipids were assayed using Advia 1650 (Siemens, New York, NY) in 2007, and a Hitachi Automatic Analyzer 7600 (Hitachi, Tokyo, Japan) since 2008. All blood samples were analyzed according to the standard protocol. LDL-C, atherogen index (AI), and homeostatic model assessment of insulin resistance (HOMA-IR) were calculated using the following equations.

\[ \text{LDL-C} = \text{TC} - \text{HDL-C} - (\text{TG}/5) \]  \hspace{1cm} (26)
\[ \text{AI} = (\text{TC} - \text{HDL-C})/\text{HDL-C} \]  \hspace{1cm} (27)
\[ \text{HOMA-IR} = \text{FBS} \times \text{fasting insulin (μIU/mL)/405} \]  \hspace{1cm} (28)

Dietary intake assessment. Dietary intake data was derived from a nutrition survey, which was collected by trained dietitians using a 24-h dietary recall through face-to-face interviews at the subjects’ homes. For the assessment of flavonoid intake, we used the flavonoid database developed for the Korean population (29). The total food intake was assessed by calculating the sum of the cereals, potatoes, sugar, beans, nuts, vegetables, mushrooms, fruits, seaweeds, beverages, and animal foods. Vegetable intake included pickled and salted vegetables but did not include potatoes or seaweeds. Fruit and vegetable intake included dried, liquid or fresh types of fruits and vegetables. This flavonoid database contains values for six subclasses (anthocyanidins, flavan-3-ols, flavanones, flavones, flavonols, and isoflavones) of flavonoids expressed in milligrams per 100 g of edible portions of foods. A total of 1,549 food items was included in the flavonoid database, which covered 85% of all plant foods, and included 96% of all plant foods mainly consumed by Koreans (29). The analysis of each individual’s dietary flavonoid intake was conducted by combining the flavonoid database and the 24-h dietary recall data in the KNHANES IV–V (2007–2012).

Statistical analysis. All statistical analyses were conducted using the SAS PROC SURVEY procedure (SAS version 9.3; Statistical Analysis System, Cary, NC). Data were presented as percentages for categorical variables and mean±standard error (SE) for continuous variables. To evaluate the significance of the difference between the NFG group and the T2DM group, SURVEY-REG tests were used. A multiple regression analysis was
Table 1. General characteristics of the subjects.

|                     | NFG  | T2DM | p value |
|---------------------|------|------|---------|
| **Age (y)**         | 45.3±0.2 | 51.4±0.9 | <0.0001 |
| **Education**       |      |  | <0.0001 |
| Elementary school or lower | 1,739 (17.5) | 99 (36.2) |          |
| Middle school       | 754 (10.3) | 34 (16.9) |          |
| High school         | 2,903 (41.3) | 61 (31.1) |          |
| College or higher   | 2,342 (30.9) | 31 (15.8) |          |
| **Health behavior** |      |  |          |
| Current smoker      | 363 (5.4) | 12 (6.6) | 0.5526   |
| Regular drinker     | 3,173 (43.8) | 79 (38.3) | 0.2385   |
| Regular exercise    | 3,759 (48.1) | 111 (48.0) | 0.9764   |
| Employed            | 4,040 (52.7) | 108 (48.9) | 0.3467   |
| **Household income**|  |  | <0.0001 |
| 1st quartile (lowest) | 1,192 (12.5) | 63 (25.1) |          |
| 2nd quartile        | 1,839 (25.2) | 72 (37.8) |          |
| 3rd quartile        | 2,308 (30.7) | 49 (20.0) |          |
| 4th quartile (highest) | 2,399 (31.6) | 41 (17.1) |          |
| **Residential area**|      |  | 0.4072   |
| Urban               | 6,026 (81.0) | 165 (78.2) |          |
| Rural               | 1,712 (19.0) | 60 (21.8) |          |
| **Family history**  | 752 (9.9) | 30 (12.8) | 0.2334   |
| Menopausal status   | 2,361 (24.1) | 113 (40.0) | <0.0001 |

NFG, normal fasting glucose; T2DM, type 2 diabetes mellitus.
Values are presented as mean ± standard error or frequency (%).

Table 2. Anthropometric and clinical characteristics of the subjects.

|                     | NFG  | T2DM | p value |
|---------------------|------|------|---------|
| **BMI (kg/m²)**     | 22.84±0.05 | 25.67±0.29 | <0.0001 |
| Waist circumference (cm) | 76.64±0.14 | 86.25±0.82 | <0.0001 |
| SBP (mmHg)          | 110.95±0.23 | 121.44±1.47 | <0.0001 |
| DBP (mmHg)          | 72.39±0.15  | 76.27±0.87  | <0.0001 |
| TC (mg/dL)          | 186.76±0.49 | 210.27±3.10 | <0.0001 |
| TG (mg/dL)          | 101.89±0.92 | 163.43±8.43 | <0.0001 |
| HDL-C (mg/dL)       | 51.13±0.17  | 45.96±0.76  | <0.0001 |
| LDL-C (mg/dL)       | 115.42±0.43 | 133.70±3.08 | <0.0001 |
| AI                  | 2.79±0.01   | 3.74±0.09   | <0.0001 |
| LDL-C/HDL-C         | 2.35±0.01   | 2.99±0.08   | <0.0001 |
| TG/HDL-C            | 2.20±0.03   | 3.91±0.25   | <0.0001 |
| TC/HDL-C            | 3.79±0.01   | 4.74±0.09   | <0.0001 |
| FBS (mg/dL)         | 88.88±0.09  | 151.45±4.29 | <0.0001 |
| HbA1c (%)           | 5.46±0.01   | 7.64±0.16   | <0.0001 |
| Insulin (µIU/mL)    | 9.06±0.07   | 11.73±0.58  | <0.0001 |
| HOMA-IR             | 2.00±0.02   | 4.23±0.23   | <0.0001 |

NFG, normal fasting glucose; T2DM, type 2 diabetes mellitus; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; TC, total cholesterol; TG, triglyceride; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; AI, atherogenic index; FBS, fasting blood sugar; HbA1c, glycosylated hemoglobin; HOMA-IR, homeostasis model assessment of insulin resistance.
Values are presented as mean ± standard error.
Adjusted: Age, body mass index, education, and menopausal status were adjusted.
performed to determine the association between dietary intakes of food, nutrients, and flavonoid intake and the CVD risk factors. Odds ratios (ORs) and 95% confidence intervals (CIs) of T2DM and high levels of CVD risk factors depending on dietary flavonoid intake above vs. below the 25th percentiles were estimated by using SURVEYLOGISTIC tests. Potential confounders were included in a multiple regression and multiple logistic regression as covariates (age, BMI, education, and menopausal status). These covariates were significantly different between the NFG group and the T2DM group in SURVEYREG tests.

All reported probability tests were two-sided, and the difference was considered statistically significant at \( p<0.05 \).

**RESULTS**

**General characteristics**

As shown in Table 1, the mean age in the T2DM group (51.4±0.9 y) was significantly higher than in the NFG group (45.3±0.2 y) \((p<0.0001)\). Subjects with T2DM were less educated \((p<0.0001)\), and had lower household income \((p<0.0001)\), and there was a higher proportion of subjects with menopausal status \((p<0.0001)\) in the NFG group. Healthy behavior, employment status, residential area and family history were not significantly different between the NFG group and the T2DM group.

**Anthropometric and clinical characteristics**

The mean BMI and waist circumference were higher in the T2DM group than in the NFG group \((p<0.0001)\). After adjustment for age, BMI, education, and menopausal status, the means of SBP \((p<0.0001)\), TC \((p<0.0001)\), TG \((p<0.0001)\), LDL-C \((p=0.0024)\), AI \((p<0.0001)\), LDL-C/HDL-C \((p<0.0001)\), TG/HDL-C \((p<0.0001)\), and TC/HDL-C \((p<0.0001)\) were significantly higher in the T2DM group than in the NFG group. HDL-C levels \((p=0.0030)\) in the T2DM group were significantly lower than in the NFG group. The mean levels of FBS \((p<0.0001)\), HbA1c \((p<0.0001)\), fasting insulin \((p=0.0008)\), and HOMA-IR \((p<0.0001)\) were significantly higher in the T2DM group than in the NFG group (Table 2).

**Dietary food, nutrient, and flavonoid intakes**

The T2DM group consumed fewer fruits \((p=0.0265)\) than did the NFG group after adjusting for covariates. The T2DM group consumed less anthocyanidins \((p=0.0320)\) and flavones \((p=0.0006)\) than the NFG group did. The mean intakes of flavan-3-ols, flavonols, isoflavones, and total flavonoids were not significantly different between the T2DM group and the NFG group (Table 3).

**Multiple regression analysis of dietary intakes of anthocyanidins and flavones and CVD risk factors**

A multiple regression analysis after adjusting for covariates revealed a significant negative association between the intake of dietary flavones and the SBP \((\beta=-0.1309, p=0.0053)\), TG \((\beta=-0.3746, p=0.0073)\), TG/HDL-C \((\beta=-0.0084, p=0.0460)\), and HOMA-IR \((\beta=-0.0157, p=0.0127)\). Dietary anthocyanin intake was positively associated with LDL-C \((\beta=0.0129, p=0.0409)\), fasting serum insulin \((\beta=0.0022, p=0.0213)\), and HOMA-IR \((\beta=0.0006, p=0.0151)\), but these associations disappeared after

### Table 3. Dietary food, nutrient and flavonoid intakes of the subjects.

|                  | NFG \((n=7,738)\) | T2DM \((n=225)\) | \( p \) value |
|------------------|--------------------|------------------|-------------|
| **Food intake (g/d)** |                    |                  |             |
| Total food intake  | 1,244.42±9.31      | 1,189.48±46.64   | 0.2470      |
| Vegetables        | 297.54±3.20        | 302.16±17.88     | 0.7978      |
| Fruits            | 214.20±4.99        | 161.46±16.90     | 0.0028      |
| **Nutrient intake** |                    |                  |             |
| Energy (kcal/d)   | 1.687.25±9.04      | 1.609.40±49.96   | 0.1242      |
| Carbohydrate (g/d)| 287.14±1.66        | 272.67±7.63      | 0.0624      |
| Protein (g/d)     | 60.79±0.42         | 57.85±2.59       | 0.2603      |
| Fat (g/d)         | 33.43±0.36         | 31.04±2.14       | 0.2703      |
| **Flavonoid intakes (mg/d)** |        |                  |             |
| Anthocyanidins    | 27.67±1.05         | 22.00±2.48       | 0.0273      |
| Flavon-3-ols      | 21.86±0.89         | 25.09±6.17       | 0.6044      |
| Flavanones        | 9.33±0.53          | 5.91±1.39        | 0.0019      |
| Flavones          | 1.00±0.05          | 0.69±0.07        | 0.0001      |
| Flavonols         | 25.19±0.43         | 22.31±2.06       | 0.1704      |
| Isoflavones       | 22.43±0.43         | 21.82±2.13       | 0.7816      |
| Total flavonoids  | 107.40±1.69        | 97.81±8.11       | 0.2468      |

NFG, normal fasting glucose; T2DM, type 2 diabetes mellitus.
Values are presented as mean±standard error.
Adjusted: Age, body mass index, education, and menopausal status were adjusted.
ORs and 95% CIs of the T2DM and high level of CVD risk factors for subjects above the 25th percentile compared with those below the 25th percentile for flavone intake

After adjusting for covariates, the odds ratio for the prevalence of T2DM in the group with flavone intake above the 25th percentile (<0.25 mg/d) versus those with flavone intake below the 25th percentile (≥0.25 mg/d) was 0.593 (95% CI: 0.414–0.847). There was no significant relationship between a high level of CVD risk factors and dietary flavone intake after adjusting for covariates (Table 5).

**DISCUSSION**

The results of this study showed that the T2DM group had lower intakes of anthocyanidins and flavones compared to the NFG group. This resulted from the lower consumption of fruits by the T2DM group because there was no difference between the NFG group and the T2DM group in vegetable intake. In the multiple regression analysis, the dietary flavone intake was negatively associated with SBP, TG, TC/HDL-C, and HOMA-IR. The odds for the prevalence of T2DM were lower among individuals with a flavone intake above the 25th percentile in comparison with an intake below the 25th percentile.

There is growing evidence based on human research that dietary intake of flavonoids or flavonoid-rich foods can be related with CVD risk factors. In the present study, we found a negative association between dietary flavone intake and SBP. These results can be supported by several studies that have investigated the antihypertensive properties of flavones. Higher intake of flavones has been inversely associated with reduced pulse wave velocity (30) and urinary F2-isoprostanes (31) in the general population. Among several flavone subclasses, Cassidy et al. in their prospective study have identified that luteolin and apigenin were capable of reducing blood pressure (32).

SBP, systolic blood pressure; DBP, diastolic blood pressure; TC, total cholesterol; TG, triglyceride; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; AI, atherogenic index; FBS, fasting blood sugar; HOMA-IR, homeostasis model assessment of insulin resistance.

Adjusted: Age, body mass index, education, and menopausal status were adjusted.
Table 5. Odds ratio and 95% confidence interval of T2DM and high level of CVD risk factors for subjects above the 25th percentile for flavone intake compared with those below the 25th percentile (n=7,963).

| Flavones                        | <25 percentiles (<0.25 mg/d) | ≥25 percentiles (≥0.25 mg/d) |
|---------------------------------|------------------------------|------------------------------|
| OR (95% CI) for T2DM            |                              |                              |
| Unadjusted                      | 1.00 (ref)                   | 0.546 (0.388–0.767)          |
| Adjusted                        | 1.00 (ref)                   | 0.593 (0.414–0.847)          |
| OR (95% CI) for SBP (≥140 mmHg) |                              |                              |
| Unadjusted                      | 1.00 (ref)                   | 0.757 (0.602–0.951)          |
| Adjusted                        | 1.00 (ref)                   | 1.154 (0.891–1.495)          |
| OR (95% CI) for TG (≥150 mg/dL) |                              |                              |
| Unadjusted                      | 1.00 (ref)                   | 0.818 (0.693–0.965)          |
| Adjusted                        | 1.00 (ref)                   | 0.941 (0.789–1.122)          |
| OR (95% CI) for TG/HDL-C (≥1.76; median) | |                              |
| Unadjusted                      | 1.00 (ref)                   | 0.924 (0.818–1.045)          |
| Adjusted                        | 1.00 (ref)                   | 1.018 (0.893–1.160)          |
| OR (95% CI) for HOMA-IR (median; ≥1.87) | |                              |
| Unadjusted                      | 1.00 (ref)                   | 1.059 (0.924–1.214)          |
| Adjusted                        | 1.00 (ref)                   | 1.060 (0.920–1.221)          |

T2DM, type 2 diabetes mellitus; SBP, systolic blood pressure; TG, triglyceride; HDL-C, high-density lipoprotein cholesterol; HOMA-IR, homeostasis model assessment of insulin resistance.

Adjusted: Age, body mass index, education, and menopausal status were adjusted.

Oxidation production and decrease endothelin production, resulting in the relaxation of vascular smooth muscle. Jennings et al. (17) in a cross-sectional study found that higher intakes of flavones were associated with improvements in C-reactive protein, a biomarker of adiposity-associated inflammation.

We also observed that dietary flavone intake was negatively associated with TG and TG/HDL-C ratios. A study (34) on fructose-induced insulin resistant hamsters showed that the supplementation of citrus polymethoxylated flavones decreased serum TG levels and reduced TG contents in the liver and heart. Citrus polymethoxylated flavones were reported to inhibit apolipoprotein B secretion (35). Ji et al. (36) in their study on hyperlipidemic rats showed that CM108, a flavone derivative, increased HDL-C, while decreasing TG, TC and LDL-C. It also activated PPARs capable of upregulating apolipoprotein A1 and ATP binding cassette transporter A1, and thus increasing the formation of HDL (37).

Our study also showed that dietary flavone intake was negatively associated with HOMA-IR, which is known as a marker of insulin resistance. In particular, in our study the odds ratio for the risk of T2DM was lower in the subjects at or above the 25th percentile of flavone intake in comparison with those below the 25th percentile. Jennings et al. (17) in a cross-sectional study, reported that higher flavone intake in women was associated with significantly lower insulin resistance (HOMA-IR) as a result of decreased insulin concentrations. Other studies have shown that flavones improve insulin resistance both in vitro (38) and in vivo (34). Bumke-Vogt et al. (39) reported that flavones showed an antidiabetic effect by inhibiting the gene expression of gluconeogenic and lipogenic enzymes such as glucose-6-phosphatase and fatty-acid synthase in human cell lines.

In the present study, the mean intake of flavones was significantly lower in the T2DM group (0.69 mg/d) than in the NFG group (1.0 mg/d). A study (40) based on the KNHANES 2008 data, in female subjects aged 30–49 y and 50–64 y, reported that the estimated mean value of flavone intake was 1.03 mg/d and 1.16 mg/d respectively. Kim et al. (41) in a study using the KNHANES 2010–2012 data reported that intake of flavonoids among Koreans was lower than in Western countries. A systemic review of all published randomized controlled trials by Hooper et al. (42) reported that flavones are abundant in tea and citrus fruits and estimated that the daily intake of flavones was 1.6 mg/d. As evident from the decreased intake of flavonoids, the intake of fruits was ~25% lower in the T2DM group in our study. In a study (43) conducted on Iranians, similar to our study findings, fruit consumption was significantly lower in the T2DM group compared to the control group. Though the results are not statistically significant, studies on Japanese (44) and Korean (45) women have shown a 17–20% decreased consumption of fruits among the T2DM group, which is similar to our study results.

These results imply that the intake of fruits and flavonoids is low in the Korean population, especially among the T2DM group. Interestingly, health professionals have been advising T2DM patients to limit their daily fruit intake. However, Christensen et al. (46) in their study mentions that restricting the intake of fruits had no statistically significant effect on glycemic control in T2DM patients. Additionally, this excessive restriction on fruit consumption may have other undesirable effects as the
daily flavonoid intake is also lowered.

There are some limitations to our study. The cross-sectional nature of the KNHANES study makes it difficult to conclude if intake of dietary flavonoids has a cause or consequence relation between prevalence of T2DM and CVD risk factors. In other words, reverse causation is a concern as a diabetes diagnosis can influence people to improve their diet after diagnosis. Despite using standard protocols, the data does not reflect all-year around intake of flavonoids as the dietary intake was measured by a one-day 24-h dietary recall. However, trained dietitians conducted and made desperate efforts to minimize potential errors when assessing dietary consumption. There is also a report available from a study which was conducted as a part of the KNHANES in 2009 (47). This report has shown that the values for total energy and other nutrients, obtained from each interview, were not much different: 1.1% for energy from an additional one-day, 24-h dietary recall to an original one-day dietary interview. The intake of nutritional supplements was not considered as the data was not collected. Nevertheless, this is the first study conducted, among Korean women aged ≥30 y to investigate the association between flavonoid intake and CVD risk factors among T2DM patients and individuals with NFG.

In conclusion, the intakes of dietary flavones are expected to have beneficial effects on CVD in Korean women. Additionally, the results of our study can provide valuable information for further development of nutritional strategies and education for Korean women with T2DM.

Acknowledgments

This research was supported by Brain Korea 21 Plus and the Bio-Synergy Research Project (212M3A9C4048761) of the Ministry of Science, ICT and Future Planning through the National Research Foundation.

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