Original Article

Consumption of black food decreases the risk of abdominal obesity in Korean women

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Background and Objectives: The association between black-colored foods (black foods) such as black beans, known for their high antioxidant capacity, and the prevention of metabolic diseases has been explored, but not in a large population. Therefore, this study examined relationships between the consumption of black foods and metabolic syndrome in Korean adults. **Methods and Study Design:** Data from 9,499 40-65-year old subjects (3,675 men and 5,824 women) from the 2010-2015 Korea National Health and Nutrition Examination Survey were used in the analysis. Black food consumption was estimated using 24-h dietary recall data, and analyses were performed according to black food consumer and non-consumer groups. **Results:** The average total consumption of black foods was higher in women than men. The total black food consumer group in women had a 24% reduced risk of abdominal obesity than the non-consumer group (p=0.007). Furthermore, waist circumference decreased significantly with an increase in total black food consumption in women. High consumption of total black foods and black beans reduced the risk of abdominal obesity by 26% (p for trend=0.012) and 29% (p for trend=0.003) compared with no consumption. No risk factors for metabolic syndrome were associated with black food consumption in men. **Conclusions:** In conclusion, black foods, including black beans, may have beneficial effects on metabolic syndrome components, especially abdominal obesity.

Key Words: antioxidants, anthocyanins, metabolic syndrome, abdominal obesity, waist circumference

INTRODUCTION

Metabolic syndrome is characterized by several interrelated metabolic disorders accompanying central obesity, dyslipidemia, hypertension, and impaired glucose tolerance[1] and is related to an increased risk of mortality.[2] According to a cohort study, subjects with metabolic syndrome had an almost two- to three-fold greater risk of cardiovascular disease, and a seven-fold greater risk of diabetes.[3]

Healthy diets including fruits and vegetables have been suggested to improve metabolic diseases. In a recent meta-analysis, fruits and vegetables were shown to have beneficial effects on blood pressure and LDL cholesterol.[4,5] Because plant-based foods, such as fruits and vegetables, are known to be a good source of bioactive compounds, the relationship of metabolic diseases with bioactive compounds has also been confirmed in epidemiological studies. In major cohort studies of the United States and European countries, it was observed that the intake of subclasses of flavonoids, which are some of the main bioactive compounds, was inversely associated with hypertension and type 2 diabetes. American adults with the highest anthocyanin intakes had 8% and 15% lower risks of hypertension and type 2 diabetes, respectively.[6,7] High intakes of flavonols and flavanols resulted in a 19% and 18% decrease in the type 2 diabetes risk in European adults.[8] In addition, the highest quintile group of flavan-3-ol intake had a 36% lower risk of high blood pressure compared with the lowest quintile group among Korean women.[9]

Several observational studies have also estimated the relationship between the intake of bioactive compounds and metabolic diseases by estimating the intake of bioactive compound-rich foods. For example, a high intake of blueberries, strawberries, and apples, which are rich in anthocyanin, reduces the risk of type 2 diabetes.[7,10] According to Yuan et al, carotene-rich fruits including tangerines and oranges have a beneficial effect on the prevention of hypertriglyceridemia, whereas no significant association could be found for carotene-rich vegetables, including carrots and spinach.[11]

One of the properties of bioactive compounds beneficial for disease prevention, such as phenolic acids, is high antioxidant activity, which inhibits oxidation processes.[12] The antioxidant activity of food can vary depending on its color. For example, black beans possess a significantly

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higher total phenolic content (TPC), total flavonoid content (TFC), 2,2-diphenyl-1-pircrylhydrazyl radical scavenging ability, and oxygen radical absorption capacity (ORAC), which are measures of the antioxidant activity of food, than those of other pale colored (green, yellow, and white) legumes.[13] Furthermore, the TPC and TFC are higher in black and purple rice than in other colors of rice.[14-16] Therefore, it is necessary to explore the relationships between the consumption of black food and diseases.

Consumption of black- or dark-colored foods, the colors of which range from dark purple to black, is negatively associated with metabolic disorders. Black bean and black bean seed coat extracts were found to inhibit lipid accumulation and induce adipocyte differentiation in an insulin-sensitive cell line and a diabetic mice model,[17,18] while black rice extract was found to reduce triglyceride (TG) levels in dyslipidemic rats.[19] In addition, consumption of dark-colored fruits or vegetables, such as black mulberries, blueberries, and eggplants, has inhibitory effects on inflammation, adipogenesis, and angiogenesis.[20-22]

However, no epidemiological study has investigated the potential association between black food consumption and diseases in a large population. Therefore, this study examined the relationships between black food consumption and the features of metabolic syndrome in Korean adults.

METHODS

Study subjects

This study used data from 48,482 subjects who participated in the 2010-2015 Korea National Health and Nutrition Examination Survey (KNHANES), a nationally ongoing surveillance system initiated in 1998 by the Korea Centers for Disease Control and Prevention (KCDC).[23] We extracted information from 17,859 40-65-year old adults from the 2010-2015 KNHANES because of their high prevalence of metabolic syndrome. Only 9,499 subjects (3,675 men and 5,824 women) were used in the analysis. Those diagnosed with or receiving treatment/medication, for hypertension, hyperlipidemia, or diabetes (n=5,551), lactating or pregnant women (n=9), those with an implausible energy intake (<600 kcal/day or >5,000 kcal/day, n=1,674), and those with missing variables in the health examination survey (n=1,126) were excluded. Data collection protocols were approved by the Institutional Review Board of the KCDC (nos.: 2010-02CON-21-C, 2011-02CON-06-C, 2012-01EXP-01-2C, 2013-07CON-03-4C, and 2013-12EXP-03-5C), and written consent was obtained from all participants.

Dietary assessment

Black food consumption was estimated using 24-h dietary recall data. Trained dietitians administered a 24-h dietary recall survey through face-to-face interviews at each participant's home. We selected items of black food from plant food among the KNHANES food database and categorized them into five black food groups: black rice, black bean, black fruit, black vegetable, and black sesame. We included purple colored foods as well as black colored foods in the black food groups because black and purple colors have similar characteristics, such as a similar antioxidant capacity.[24] The food items in each group are: black rice, black bean, blackberries, blueberries, mulberries, Korean raspberries (Bokbunja), grapes, black mushroom (tree ears), pickled black olives, purple colored lettuce and cabbages, eggplants, beet, kohlrabi, and black sesame. The consumption of each black food group was assessed by summing the individual food intakes of each food group. We also estimated the intake of anthocyanin, which is present at high levels in black-colored foods,[25,26] from black foods using the US Department of Agriculture Flavonoid database for black fruits and vegetables[27] and a published study on black rice and black beans.[28] The anthocyanin content was recorded for each black food item in the KNHANES food database, and that of the remaining food items that had no available information on anthocyanin content was assigned the estimated value, which was calculated by multiplying the content of a similar food item by a moisture conversion factor which has similar nutrient content but different preparation or processing methods.[29]

All subjects were divided into black food consumers or non-consumers. If a participant consumed at least one black food, the subject was considered a black food consumer. All analyses were conducted by comparing the black food consumer and non-consumer groups. The consumers of each black food group were divided into low and high consumption groups to compare them with the non-consumption group in subsequent analyses. In addition, fruit, vegetable, grain, legume and legume products, and nuts and seeds groups were categorized to compare the intake of the major food sources of bioactive compounds[29] between black food consumers and non-consumers.

Assessment of covariates

Sociodemographic and health-related data were obtained from an interview conducted by trained staff members and were used as covariates. Sex, age, living area, household income, marital status, and education were included as sociodemographic variables. Living area was divided into two categories: urban and rural. Household income was divided into four categories: lowest, lower middle, upper middle, and highest. Marital status was divided into three categories: married, separated/divorced/bereaved, and single. Education level was divided into four categories: ≤elementary school graduate, middle school graduate, high school graduate, and ≥college graduate. Physical activity, drinking, and smoking status were included as health behavior variables. Physical activity was categorized as "never or rarely (≤1 day/week)", "occasionally (2-4 day/week)", and "usually (≥5 day/week)", with physical activity being considered the equivalent of walking for 10 minutes or more each day during the week before the interview. Drinking was categorized as "never or rarely," "≤1/month", "2-4/month", "2-3/week", and "≥4/week" based on the drinking frequency during the year before the interview. Smoking status was divided into "yes (current smoker)" and "no (non-smoker and former smoker)".

Definition of metabolic syndrome

Data from a health examination were used to diagnose metabolic syndrome. The participants were considered to be diagnosed with metabolic syndrome if they had three or more of the following features: waist circumference ≥90 cm for men and ≥85 cm for women, TG levels ≥150 mg/dL, HDL cholesterol levels <40 mg/dL for men and <50 mg/dL for women, SBP ≥130 mmHg or DBP ≥85 mmHg, and fasting plasma glucose levels ≥100 mg/dL. The waist circumference criteria were based on the standard reference for Koreans,[30] while the other criteria were based on the National Cholesterol Education Program Adult Treatment Panel III.[31]

The health examination was carried out based on standardized protocols by trained medical staff members. The waist circumference was measured horizontally at the midpoint between the lowermost part of the rib cage and the uppermost iliac crest at the mid-axillary line, to the nearest 0.1 cm. Blood pressure was measured three times in the right arm using a mercury sphygmomanometer (Baumanometer® Wall Unit 33, W.A. Baum Co., Copiague, NY, USA). The participants were asked to sit quietly in a chair and rest at least 5 minutes before the measurement. The blood pressure value used in this analysis was the average of the second and third blood pressure measurements. A blood sample was collected from each participant after at least an 8-hour fast and immediately centrifuged and stored at 4°C at the examination site. The sample was transported to the Central Testing Institute in cold storage, and levels of the blood parameters TG, HDL cholesterol, and fasting plasma glucose were analyzed on the same day using the Hitachi Automatic Analyzer 7600 (2010–2012) or 7600-210 (2013–2015) (Hitachi, Ltd., Tokyo, Japan).

Statistical analysis

SAS 9.4 (SAS Institute, Cary, NC, USA) was used to perform all statistical analyses. Sampling weights, clusters, and strata, which accounted for the complex multistage sampling design of the survey, were applied in all statistical analyses using PROC SURVEY procedures.[32] The overall consumption of total black food and black food subgroups by participants were described using means and standard errors obtained from the PROC SURVEYREG procedure. The general characteristics, nutrient and food intake, and the association of black food consumption with metabolic syndrome risk factors were assessed. The chi-squared test was used through the PROC SURVEYFREQ procedure, and a Student's t-test was operated through the PROC SURVEYREG to estimate differences in the distribution of categorical and continuous variables, respectively. The nutrient and food intakes and the associations of black food consumption with metabolic syndrome risk factors were estimated by a multivariate regression model using the PROC SURVEYREG command or a multivariate logistic regression model using the PROC SURVEYLOGISTIC command in SAS. Odds ratios (ORs), 95% confidence intervals (95% CI), and *p* values for trends for metabolic components across the black food consumer groups were calculated using the black food non-consumer group as the reference group. All multivariate analyses were adjusted for age, living area, household income, marital status, education, physical activity, drinking, smoking status, and energy intake.

RESULTS

Black food consumption of the subjects

Table 1 shows the black food consumption of the participants. The average consumption of black food was 30.1±2.3 g/day, and 60.5% (n=5,866) of all subjects consumed black food (data not shown). The average black food consumption of women was significantly higher than that of men (men 25.6±2.1 g/day and women 34.5±3.5 g/day, *p*=0.016). Black fruit was the most heavily consumed black food (19.6±2.2 g/day) among the black food subgroups, whereas on a percentage basis black bean (n=3,344, 33.6%) was the most widely consumed black food among the black food subgroups (black rice, n=2,973, 30.8%; black fruit, n=1,235, 13.2%; black vegetable, n=1,418, 14.8%; black sesame, n=184, 1.8%) (data not shown). The consumption of black fruit was significantly higher in women than in men (men 15.4±2.0 g/day and women 23.6±3.5 g/day, *p*=0.024), while the consumption of black beans was significantly lower in women than in men (men 4.0±0.2 g/day and women 3.5±0.1 g/day, *p*=0.040). The consumption of black sesame was very low. We compared the black food consumer and non-consumer groups and conducted a further analysis by dividing the participants according to the black food consumption level: non-, low, and high consumption groups.

General characteristics of the subjects

Table 2 shows the general characteristics of the study subjects. Most subjects (60.5%) were in the total black food consumer group, and the percentage of black food consumers was higher in women (54.5%) than men. The

Table 1. Black-colored food consumption among 40–65-year-old Korean adults

Black food consumption (g/day)	Total (n=9,499)	Men (n=3,675)	Women (n=5,824)
Total black food	30.1±2.3[†]	25.6±2.1[‡]	34.5±3.5[‡]
Black rice	2.2±0.1	2.2±0.1	2.2±0.1
Black bean	3.7±0.1	4.0±0.2[‡]	3.5±0.1[‡]
Black fruit	19.6±2.2	15.4±2.0[‡]	23.6±3.5[‡]
Black vegetable	4.5±0.3	3.9±0.4	5.1±0.5
Black sesame	0.0±0.0	0.0±0.0	0.0±0.0

[†]All values are expressed as means±SE.
[‡]Significantly different between men and women (*p*<0.05).

Table 2. General characteristics of consumers and non-consumers of black-colored foods among 40–65-year-old Korean adults

	Black food non-consumers	Black food consumers	*p* value†
Subjects (n, %)	3,633 (39.5%)	5,866 (60.5%)	<0.001
Women (n, %)	2,074 (46.1%)	3,750 (54.5%)	<0.001
Age (mean±SE)	49.0±0.1	49.9±0.1	<0.001
Living area (%)			0.020
Urban	79.1	81.7	
Rural	20.9	18.3	
Household income (%)			0.008
Lowest	10.9	8.4	
Lower middle	26.2	24.6	
Upper middle	29.8	30.6	
Highest	33.1	36.3	
Marital status (%)			<0.001
Married	85.2	89.1	
Separated/divorced/bereaved	10.1	8.3	
Single	4.7	2.7	
Education (%)			0.002
≤ Elementary school graduate	14.8	12.2	
Middle school graduate	12.8	13.9	
High school graduate	38.7	42.2	
≥ College graduate	33.7	31.7	
Physical activity (%)			<0.001
Never or rarely (≤1 day/week)	28.6	23.0	
Occasionally (2-4 days/week)	30.9	33.1	
Usually (≥5 days/week)	40.4	43.9	
Drinking (%)			<0.001
Never or rarely	16.0	17.4	
≤1 time/month	23.6	25.5	
2-4 times/month	26.7	28.4	
2-3 times/week	21.0	20.3	
≥4 times/week	12.8	8.6	
Smoking status (%)			<0.001
Yes	28.6	20.8	
No	71.4	79.2	

†*p* values were estimated using the chi-squared test for categorical variables and Student's t-test for continuous variables

mean age was 49.9±0.1 years in the black food consumer group and 49.0±0.1 years in the non-consumer group. The black food consumer group was more likely to live in an urban area (81.7%) with a spouse (89.1%) and had a higher income (upper middle 30.6% and highest 36.3%) than the non-consumer group. In addition, the black food consumers were more physically active and drank and smoke less compared with the non-consumers.

Nutrient and food intake according to total black food consumption

The energy intake was significantly different between total black food consumers and non-consumers in men and women, as shown in Table 3. Men (consumers 2426±31.5 kcal/day and non-consumers 2299±34.4 kcal/day, $p<0.001$) and women (consumers 1832±33.8 kcal/day and non-consumers 1713±37.7 kcal/day, $p<0.001$) who consumed black food had a greater energy intake than those that did not consume black food. The energy-adjusted carbohydrate, protein, and fat intakes were not different between black food consumers and non-consumers in men. However, carbohydrate intake was significantly lower (consumers 281±3.3 g/day and non-consumers 286±3.8 g/day, $p=0.043$), and protein (consumers 65.6±1.2 g/day and non-consumers 63.6±1.4 g/day, $p=0.010$) and fat (consumers 38.4±0.9 g/day and non-consumers 36.1±1.1 g/day, $p=0.001$) intakes significantly higher, in the black food consumers than non-consumers among women. Fiber intake was higher in the black food consumers than non-consumers in both men and women, and anthocyanin intake from black foods was 8.1±0.2 mg/day in men and 8.1± 0.3 mg/day in women.

The intake of major food groups was also significantly different between the total black food consumer and non-consumer groups in both men and women. The black food consumer group in both men (fruit, consumers 202±11.9 g/day and non-consumers 169±12.8 g/day, $p=0.011$; vegetables, consumers 404±8.0 g/day, non-consumers 372±8.4 g/day, $p<0.001$) and women (fruit, consumers 224±10.8 g/day and non-consumers 180±11.4 g/day, $p<0.001$; vegetables, consumers 317±9.1 g/day, non-consumers 294±9.9 g/day, $p=0.019$) had higher fruit and vegetable intakes than those of the non-consumer group. The fruit intake of women in the black food consumer group was higher than that of men in the black food consumer group, while the vegetable intake of men in the black food consumer group was higher than that of women in the black food consumer group. Women in the black food consumer group had a significantly higher intake of legumes and legume products (consumers 34.2±2.3 g/day and non-consumers 28.0±2.6 g/day, $p=0.016$) than women in the non-consumer group, and men in the black food consumer group had a significantly higher intake of nuts and seeds (consumers 6.0±0.6 g/day

Table 3. Nutrient and food intakes in consumers and non-consumers of black-colored foods among 40–65-year-old Korean adult men and women

	Men (n=3,675)			Women (n=5,824)		
	Black food non-consumer (n=1,559)	Black food consumer (n=2,116)	*p* value†	Black food non-consumer (n=2,074)	Black food consumer (n=3,750)	*p* value†
Nutrient intake						
Energy (kcal/day)‡	2299±34.4†	2426±31.5	<0.001	1713±37.7	1832±33.8	<0.001
Carbohydrate (g/day)§	373±3.5	376±3.2	0.473	286±3.8	281±3.3	0.043
Protein (g/day)§	85.8±1.3	86.8±1.0	0.391	63.6±1.4	65.6±1.2	0.010
Fat (g/day)§	50.3±1.0	50.2±0.8	0.930	36.1±1.1	38.4±0.9	0.001
Fiber (g/day)§	16.9±0.5	19.3±0.5	<0.001	16.0±1.0	18.2±0.8	<0.001
Anthocyanin from black foods (mg/day)§	0	8.1±0.2	<0.001	0	8.1±0.3	<0.001
Food intake§						
Fruit (g/day)	169±12.8	202±11.9	0.011	180±11.4	224±10.8	<0.001
Vegetable (g/day)	372±8.4	404±8.0	<0.001	294±9.9	317±9.1	0.019
Grain (g/day)	254±4.9	257±4.3	0.537	174±5.4	170±4.9	0.269
Legume and legume products (g/day)	46.5±3.3	46.8±3.0	0.942	28.0±2.6	34.2±2.3	0.016
Nuts and seeds (g/day)	4.7±0.5	6.0±0.6	<0.05	4.8±0.6	5.0±0.5	0.787

†All values and p values were estimated using a multivariate regression model.
‡The multivariate model included age, living area, household income, marital status, education level, physical activity level, and drinking and smoking statuses.
§The multivariate model included age, living area, household income, marital status, education level, physical activity level, drinking and smoking statuses, and energy intake.

Table 4. Multivariate adjusted odds ratios (ORs) and 95% confidence intervals (CIs) for metabolic syndrome components in consumers and non-consumers of total black-colored foods among 40–65-year-old Korean adult men and women

	Men (n=3,675)				Women (n=5,824)			
	Black food non-consumer (n=1,559)	Black food consumer (n=2,116)		*p* value†	Black food non-consumer (n=2,074)	Black food consumer (n=3,750)		*p* value†
Abdominal obesity	1.00	1.06†	(0.87-1.27)	0.578	1.00	0.76	(0.62-0.93)	0.007
Elevated triglyceride	1.00	1.11	(0.92-1.33)	0.276	1.00	0.93	(0.76-1.13)	0.449
Low HDL cholesterol	1.00	1.08	(0.88-1.31)	0.469	1.00	0.96	(0.81-1.12)	0.585
High blood pressure	1.00	0.99	(0.82-1.18)	0.876	1.00	0.90	(0.74-1.10)	0.305
Elevated fasting glucose	1.00	1.11	(0.93-1.32)	0.250	1.00	1.02	(0.85-1.24)	0.812
Metabolic syndrome	1.00	1.12	(0.91-1.37)	0.290	1.00	0.86	(0.69-1.08)	0.188

†All values and p values were estimated using a multivariate logistic regression model. The multivariate model included age, living area, household income, marital status, education level, physical activity level, drinking and smoking statuses, and energy intake.

and non-consumers 4.7±0.5 g/day, $p<0.05$) than men in the non-consumer group.

Effect of black food consumption on metabolic syndrome risk factors

We observed that black food consumption has a preventive effect on metabolic syndrome risk factors in women. As shown in Table 4, women in the total black food consumer group had a 24% reduced risk of abdominal obesity than that of non-consumer women (OR: 0.76, 95% CI: 0.62-0.93, $p=0.007$). In the analysis of specific types of black foods, women who consumed black beans had a 26% reduced risk (OR: 0.74, 95% CI: 0.61-0.91, $p=0.004$) of abdominal obesity, and those who consumed black fruit had a 24% reduced risk (OR: 0.76, 95% CI: 0.58-1.00, $p<0.05$) of an elevated TG level compared with women who did not consume such foods (data not shown). This association remained after further adjustment for menopause status among the female subjects (data not shown). There were also no significant differences in metabolic syndrome risk factors between pre- and post-menopausal women in the black food consumer group (data not shown). None of the metabolic syndrome components was significantly associated with black food consumption in men.

To investigate the risks of metabolic syndrome components, abdominal obesity in particular, across black food consumption levels in women, we conducted further analyses by dividing the participants into non-, low, and high consumption groups. Consistent with the above results, waist circumference significantly decreased with an increase in black food consumption (non-consumption: 78.7±0.5 cm, low consumption 78.3±0.5 cm, and high consumption 77.9±0.5 cm, p for trend<0.05) in women only (Figure 1). Table 5 shows the association between consumption of total black foods or black food subgroups with abdominal obesity. High consumption of total black foods showed a 26% lower risk (OR: 0.74, p for trend=0.012), and that of black beans a 29% lower risk (OR: 0.71, p for trend=0.003), of abdominal obesity compared with the non-consumption group.

DISCUSSION

We found that consumption of black-colored foods is associated with a decreased risk of abdominal obesity among metabolic syndrome risk factors in 40-65-year old Korean adult women using data from the 2010-2015 KNHANES. Women in the total black food consumer group had a significant 24% decreased risk of abdominal obesity after adjustment for potential covariates. Waist circumference also significantly decreased with increasing consumption of total black foods in women. Moreover, high consumption of total black foods and black beans reduced the risk of abdominal obesity by 26% and 29%, respectively, compared with no consumption. The consumption of black fruit, such as black berries, blueberries, and grapes was also inversely associated with the TG level in women. Black food consumption in men was not found to be related to metabolic syndrome risk factors.

A preventive effect of black bean consumption on abdominal obesity was also found in other studies. In an 8-week randomized controlled trial, the waist circumference of overweight or obese subjects who received black soybean extracts significantly decreased.[33] It has also been reported that black soybean consumption decreased lipid profiles, such as the TG and LDL levels, in overweight or obese subjects and enhanced the antihyperlipidemic effects in type 2 diabetes patients,[33,34] although no significant association was found between lipid parameters and black bean consumption in this study (TGs in women: OR: 1.02, 95% CI: 0.84-1.24, $p=0.848$).

We also identified a relationship between black fruit

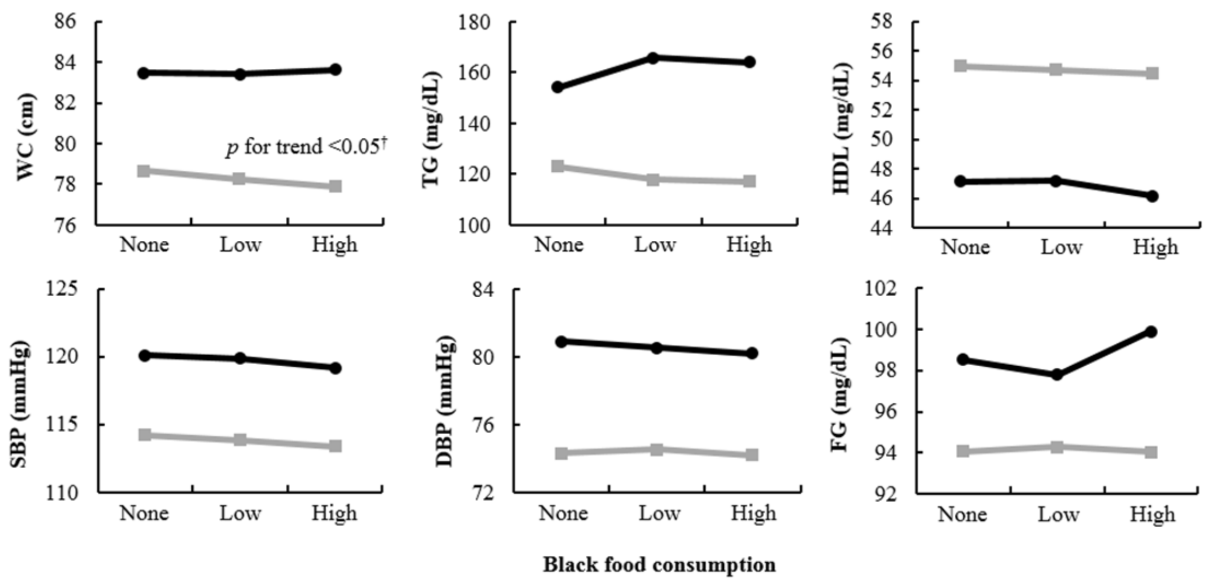

Figure 1. Patterns of metabolic syndrome components (waist circumference [WC], triglyceride [TG], high-density lipoprotein [HDL], systolic blood pressure [SBP], diastolic blood pressure [DBP], and fasting glucose [FG]) across levels of total black food consumption (non-consumers [none], lower consumers [low], and higher consumers [high]) in men (black line) and women (gray line) among 40–65-year old Korean adults. All values and p values for trend were estimated using multivariate regression models including age, living area, household income, marital status, education level, physical activity level, drinking and smoking statuses, and energy intake. †p for trend <0.05.

Table 5. Multivariate adjusted odds ratios (ORs) and 95% confidence intervals (CIs) for abdominal obesity across total black food and black food subgroup consumption levels among 40–65-year-old Korean women

	Black food consumption			*p* for trend‡
	None	Low	High	
Total black food				
n	2,074	1,874	1,876	
Total black food consumption (g/day)	0	1.3±2.4†	92.5±7.7	
Abdominal obesity	1.00	0.78 (0.62-0.99)	0.74 (0.58-0.94)	0.012
Black rice				
n	3,913	955	956	
Black rice consumption (g/day)	0	1.9±0.1	11.0±0.5	
Abdominal obesity	1.00	0.86 (0.65-1.12)	0.87 (0.67-1.14)	0.202
Black beans				
n	3,696	1,065	1,063	
Black bean consumption (g/day)	0	3.4±0.2	17.1±0.8	
Abdominal obesity	1.00	0.78 (0.59-1.02)	0.71 (0.55-0.91)	0.003
Black fruits				
n	4,986	413	425	
Black fruit consumption (g/day)	0	8.3±3.3	277.3±30.4	
Abdominal obesity	1.00	0.82 (0.55-1.20)	0.88 (0.58-1.33)	0.370
Black vegetables				
n	4,906	459	459	
Black vegetable consumption (g/day)	0	4.4±1.4	63.7±5.9	
Abdominal obesity	1.00	0.93 (0.64-1.34)	0.88 (0.63-1.24)	0.434

†All values are expressed as means±SE.
‡*p* values for trend were estimated using a multivariate logistic regression model. The multivariate model included age, living area, household income, marital status, education level, physical activity level, drinking and smoking statuses, and energy intake.

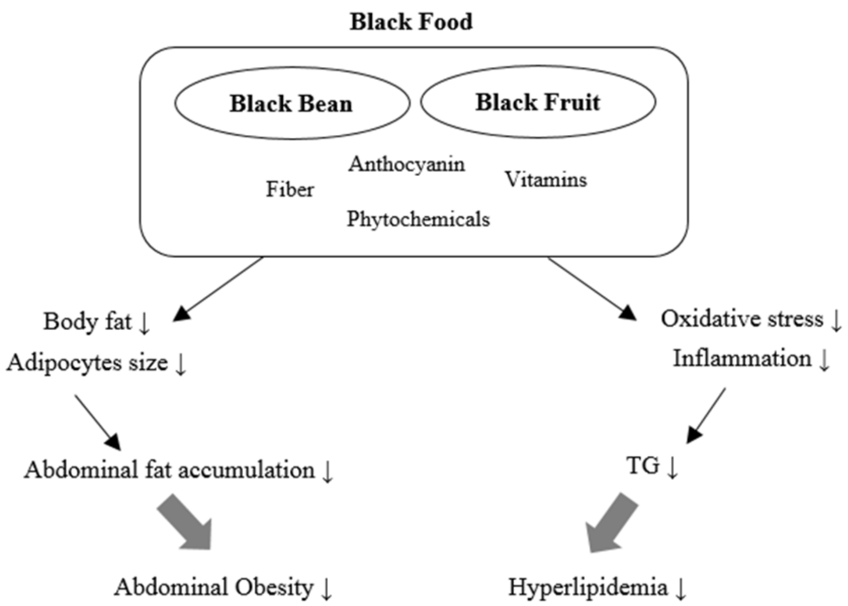

Figure 2. Conceptual diagram showing the mechanism by which black food intake potentially affects cardiometabolic risk in this study.

consumption and a reduction in the TG level, as has been observed by experimental and clinical studies.[35-38] Blackberry consumption lowered the TG level.[35] The levels of plasma TG in women was found to significantly decrease by 6-15% after a grape treatment.[36] An association between blueberry intake and reduced blood glucose and improved insulin sensitivity has been reported in animal and randomized controlled trial studies,[37,38] whereas a negative, but non-significant, association with reduced glucose was found in our study (fasting glucose in women, OR: 0.99, 95% CI: 0.76-1.28, *p*=0.923).

A higher intake of black and purple colored food can be linked to a higher anthocyanin intake. Black foods are known for their high content of anthocyanin.[25,26] Several studies have shown that TPC, TFC, and ORAC are higher in black-colored food than in food of other colors,[13-16] and anthocyanin contributes to the higher antioxidant capacity of dark-colored foods.[15] The mechanism by which anthocyanins induce the prevention of metabolic diseases has been demonstrated. In cellular studies, anthocyanins inhibited lipid accumulation in adipocytes by reducing lipogenic transcription biomarkers.[39] Furthermore, it has been recently reported that cyanidin 3-glucoside, a representative anthocyanin, improves diabetes by increasing glucose transporter 4 and decreasing retinol binding protein 4 levels.[40] It can therefore be assumed that a high rate of black food consumption leads to a high anthocyanin intake, which helps improve metabolic syndrome.

In addition to the colorant anthocyanin, other food components in black foods also affect metabolic disorders. Black beans, in particular, contain fiber, resistant starch, arginine, essential fatty acids, vitamins, lunasin, phytosterols, and phytoestrogenic isoflavones and these components and their structural properties reportedly induce low glycemic responses and reductions in lipid profiles, blood pressure, inflammation, body compositional disorders, and the risks of cardiovascular disease and diabetes.[41-45] The association between legume intake and reduced mortality was shown in an elderly cohort.[46] A conceptual diagram of the mechanism by which black food intake affects metabolic syndrome components according to the results of this study is shown in Figure 2.

The finding that the risks of metabolic syndrome components were reduced exclusively in women is partly consistent with a previous study in a Taiwanese cohort, which found that the impact of bean intake on metabolic syndrome components varied by sex.[41] A higher frequency of bean consumption showed favorable effects on lipid status and blood pressure in men, and on waist circumference and the waist-to-hip ratio in women, compared with less frequent bean consumption. These results were interpreted as indicating a difference in susceptibility to metabolic syndrome between men and women. Estrogen in beans might regulate body fat distribution, which is hormone sensitive, particularly abdominal fat.[41] We also observed that black bean consumption reduced the risk of abdominal obesity in women only. Even though we did not investigate a specific mechanism by which black beans affect fat accumulation in the abdomen, we found that antioxidant activity, which is high in black beans, inhibits lipid accumulation.[17,18,29] According to Park et al., Korean women with the highest fruit consumption had lower risks of metabolic syndrome and elevated TG levels, whereas no significant association was found in men.[47] Likewise, the fruit intake was higher in black food consumers among women than men, and the female black fruit consumers had a lower risk of elevated TG levels compared with non-consumers in this study. This association might be explained by the anti-oxidative stress and anti-inflammation activities of bioactive compounds[48,49] in various fruits, although the different mechanisms leading to sex-related differences in metabolic syndrome risk remain unknown. It is therefore necessary to investigate the mechanisms of disease prevention of a diverse range of bioactive compounds, especially food colorants, from different food groups in future experimental studies.

There were several limitations to this study. First, we could not establish a causality between consumption of black food and metabolic syndrome because this was a cross sectional study. Second, it was difficult to estimate the intake of all types of black food due to the limited number of food items listed in the database used. There were only five black food groups, with less than 20 food items considered in the study. Finally, we could not assess the relationship between the intake of diverse bioactive compounds from black foods and metabolic syndrome because there is no national bioactive compound database available in Korea.

Despite these limitations, there are many strengths to this study. We estimated the levels of black-colored food consumption and explored the effect of black-colored food consumption on metabolic syndrome features for the first time using a large data sample. Our study suggests that the consumption of black-colored foods, including black beans, may have beneficial effects on metabolic syndrome, particularly abdominal obesity. Further studies to estimate the intake of color food groups linked with bioactive compounds and their relationship with metabolic diseases are required in the form of clinical trials and prospective cohort studies.

AUTHOR DISCLOSURES

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