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Kimchi, a Fermented Vegetable, Improves Serum Lipid Profiles in Healthy Young Adults: Randomized Clinical Trial

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ABSTRACT Vegetable-based diets have generally focused on their health benefits including negative associations with the serum cholesterol concentrations. The aim of this study was to investigate whether serum lipid concentrations are influenced by the amount of kimchi intake. For the study, 100 volunteers were assigned to 2 dietary groups, low (15 g/day, $n = 50$) and high (210 g/day, $n = 50$) kimchi intake, and were housed together in a dormitory for 7 days. Identical meals except with different amount of kimchi were provided and subjects were instructed to maintain their normal physical activity. Concentrations of fasting blood glucose (FBG), total glucose, total cholesterol and low density lipoprotein (LDL)-C significantly decreased in both groups after 7 days of kimchi intake, but the effects were dose dependent. Lipid lowering effects of kimchi were more profound in the subjects with total cholesterol and LDL-C level over 190 and 130 mg/dL, respectively, in both groups. FBG was significantly decreased in the high kimchi intake as compared to the low intake group ($P = .003$). In conclusion, greater consumption of kimchi improved FBG and serum total cholesterol in young healthy adults.

KEY WORDS: • ***blood lipids*** • ***cholesterol*** • ***clinical trial*** • ***fasting blood glucose*** • ***vegetables***

INTRODUCTION

Kimchi is a Korean fermented vegetable side dish and has been increasingly recognized as a functional food and gained popularity when listed among the ''World's Healthiest Foods'' in the magazine ''Health''. Health benefit of kimchi is a low-calorie (18 kcal/100 g) and low-fat (0.5 g/100 g) plant-based food. In addition, kimchi is rich in various biological compounds such as dietary fiber, vitamin C, β-carotene, β-sitosterol, minerals, and other health promoting phytochemicals as well as lactic acid bacteria, which are derived from kimchi ingredients and/or the fermentation process.[1] Kimchi and its ingredients have been spotlighted for their health-promoting functionalities, including: anti-oxidative activity,[2] anti-aging,[3] anti-mutagenic and anti-tumor,[4] anti-microbial activity,[5] immune stimulating activity,[6] anti-obesity,[7] and anti-atherogenic effects.[8–11] In a previous study, 3-(4′-hydroxyl-3′,5′-dimethoxyphenyl)propionic acid (HDMPPA), an active principle in cabbage kimchi,[2] demonstrated anti-atherogenic activity in terms of preventing the fatty streak formation or aortic sinus.[10,11] Among the possible mechanisms, it was suggested that HDMPPA suppressed transcription rate for the enzymes responsible for the production of reactive oxygen species and also inhibited adhesion molecule expression whereas endothelial nitric oxide synthase activity in the aorta was elevated.[11] In a human study, kimchi consumption exerted favorable plasma lipid lowering effects and improved metabolic syndrome parameters in obese people.[12]

In Korea, where the aging of population is rapidly increasing and westernized lifestyle is becoming more prevalent, cardiovascular disease (CVD) and metabolic syndrome–related diseases such as type two diabetes mellitus (DM) are becoming important public health issues. In fact, during the last two decades, crude mortality from ischemic heart disease dramatically increased for men (10.3-fold increase), and women (17.5-fold increase), and diabetes-related mortality was also increased four times for men and six times for women. These tendencies are shown throughout the world. Therefore, many trials to prevent or decrease the prevalence of these degenerative diseases have been performed with modification of environmental factors such as dietary patterns and screening for biologically effective compounds from foods.

The association of dietary habits with the risk of disease such as CVD, stroke, DM etc, been extensively investigated, suggesting that a diet rich in potatoes, meat, and alcohol[13] increased the risk of metabolic syndrome, whereas a diet high in fruits/vegetables[14,15] or whole-grains[16] might decrease the risk. Thus vegetable-based diets prevail in

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Table 1. General Characteristics of the Subjects Before and After 7 Days of Kimchi Consumption

	Low group (15 g/day)		*High group (210 g/day)*		
	Mean ± SD	P *value**	*Mean ± SD*	P *value**	*Between group* P *value**
Age (years old)	22.5 ± 3.1		23.0 ± 2.8		
Height (cm)	164.9 ± 8.9		165.3 ± 7.8		
Weight (kg)	57.4 ± 12.3		58.2 ± 9.2		
BMI (kg/m^2)		.058		.147	.281
Pre	21.2 ± 2.6		21.3 ± 2.8		
Post	21.3 ± 2.6		21.4 ± 2.8		
Body fat amount (kg)		.102		.131	.161
Pre	13.3 ± 4.2		13.2 ± 4.3		
Post	13.4 ± 4.1		13.4 ± 4.1		
Body fat percentage (%)		.167		.165	.292
Pre	22.9 ± 5.4		22.6 ± 5.5		
Post	23.0 ± 5.2		22.8 ± 5.3		
Fat free mass (kg)		.175		.709	.555
Pre	44.8 ± 9.1		45.3 ± 8.0		
Post	44.9 ± 9.0		45.6 ± 7.9		
Skeletal muscle weight (kg)		.283		.328	.318
Pre	18.4 ± 5.3		19.2 ± 5.5		
Post	18.6 ± 5.3		21.8 ± 17.6		
Waist/hip ratio		.398		.090	.220
Pre	0.75 ± 0.05		0.75 ± 0.05		
Post	0.76 ± 0.05		0.76 ± 0.05		
Systolic BP (mmHg)		.011		.137	.476
Pre	123.0 ± 13.9		120.3 ± 11.7		
Post	119.6 ± 14.8		118.3 ± 13.3		
Diastolic BP (mmHg)		.052		.317	.461
Pre	70.8 ± 8.9		70.3 ± 7.7		
Post	68.7 ± 10.2		69.3 ± 8.7		

*Change from baseline to 7 days.
BMI, body mass index; BP, blood pressure.

populations with normolipidemia, demonstrating their value as health promotion-related lifestyles. Therefore the present study investigated the effect of kimchi intake in healthy adults on fasting glucose levels and serum lipid profiles by controlling the meal consumption and physical activity.

MATERIALS AND METHODS

Subjects and study design

One hundred men and women were recruited from the university through poster advertising and email campaigns. Written informed consent was obtained from all participants. The clinical study protocol was reviewed and approved by the Institutional Review Board (IRB) of University Hospital affiliated with Pusan National University (Busan, Korea) for ethical procedures and scientific care (Approval Number 2011075).

The participants were randomly assigned to two experimental groups and received two different serving sizes of kimchi (low group: 15 g/day, $n = 50$; high group: 210 g/day, $n = 50$) for 7 days. G power analysis program was used to calculate the minimum sample size required. The reason for having a low intake kimchi group in this study instead of no kimchi was that Koreans typically include at least some kimchi with their meals. To control food intake, subjects stayed at the dormitory temporarily during the 7-day experimental period, and were provided meals with identical compositions except with different amounts of kimchi. To avoid the effect of individual exercise or physical activity, they were asked to maintain their normal physical activity. For the baseline information of nutritional status, 3-day dietary records of the subjects were received. Calorie and nutrient intakes were analyzed using a diet analysis program (Can-pro, The Korean Nutrition Society, Seoul, Korea). Kimchi intake was calculated and compared between the low and high group.

Body composition, blood pressure, and blood sampling

Weight, height, and body composition were assessed by using X-Scan Plus II (Jawon Medical, Guri, Korea). Body mass index (BMI, kg/m^2), body fat amount (kg), body fat percentage (%), fat free mass (kg), skeletal muscle weight (kg), waist/hip ratio were also calculated. Blood pressure was measured by an automatic blood pressure examiner (FT-500R Plus; Jawon Medical, Guri, Korea) after resting for at least 10 min. Pre- and post-study blood samples were taken from overnight-fasted subjects. Blood concentrations

TABLE 2. COMPARISON OF PRE- AND POST-TEST KIMCHI INTAKE, TOTAL ENERGY INTAKE AND RATIOS OF NUTRIENTS

	Low group (15 g/day)	*High group (210 g/day)*	P *value**
Pre			
Kimchi intake (g/day)	44.47 ± 45.23	33.70 ± 44.98	.235
Energy (kcal)	1752.1 ± 562.6	1890.8 ± 708.4	.281
Carbohydrate (%)	55.7 ± 11.5	56.0 ± 7.7	.847
Protein (%)	16.7 ± 6.5	15.4 ± 3.1	.217
Fat (%)	27.7 ± 8.3	28.6 ± 7.6	.576
Post			
Kimchi intake (g)	15	210	
Energy (kcal)	1862.1 ± 66.5	1899.1 ± 66.5	.318
Carbohydrate (%)	58.5 ± 2.1	58.2 ± 2.1	.795
Protein (%)	18.9 ± 1.9	19.3 ± 1.9	.692
Fat (%)	22.6 ± 2.9	22.5 ± 2.9	.949

Data are presented as mean ± SD.
*Between groups.

of glucose, total cholesterol, high density lipoprotein (HDL)–cholesterol, low density lipoprotein (LDL)–cholesterol, triglyceride, and total antioxidant status were automatically measured (Modular Analytics, Roche, Germany).

Diets and kimchi

During the 7-day experimental period, the meals served to the subjects were arranged by the dietician. Serving size of vegetables and fruits except kimchi were the same for all subjects, and other foods were supplied as individual servings. Fermented kimchi (acidity 0.53%–0.66%, pH 4.5–4.7) was provided. The amount of kimchi provided to the high intake group was determined based on the recommended serving size for the vegetable which is 210 g per day for Koreans,[17] and the amount kimchi given to the low intake group was two pieces (3 cm × 4 cm, 5 g) per meal, which was considered as a minimum serving size.

Statistical analysis

Statistical analyses were performed using SPSS package 18.0. All values are presented as mean ± SD. The differences between baseline and post-test were analyzed by paired *t*-tests. The changes in base and post-test between the two groups were compared by student's *t*-test. Values were considered to be significant at $P < .05$.

RESULTS

General characteristics

No subjects dropped out and 100% completed the study due to its short duration. General characteristics of the subjects are shown in Table 1. The mean age for the low intake group is 22.5 ± 3.1 years old and that for the high intake group is 23.0 ± 2.8 years old which were not significantly different. There were also no significant differences in height (low group: 164.9; high group: 165.3 cm), and weight (kg, 57.4; 58.2), BMI, body fat mass, fat free mass and skeletal muscle weight, after 7 days of the kimchi consumption trial.

Kimchi intake, total energy intake and ratio of nutrients

As shown in Table 2, there was no significant difference in kimchi intake between the low and high group before the intervention trial. Intakes of energy and macronutrients (carbohydrate: protein: fat) between two groups were also not different. However, fat consumption decreased in post-test by 5.1% and 6.1% for the low and high group, respectively, compared with their baselines.

Fasting blood glucose

Changes in fasting blood glucose (FBG) concentrations of the subjects after 7 days of kimchi consumption are shown in Table 3. After the 7-day kimchi intervention period, there was a significant decrease in FBG concentrations in both the low (15 g/day) and high (210 g/day) group by 2.28% ($P = .002$) and 6.96% ($P < .001$), respectively. Higher kimchi intake resulted in a significantly greater decrease in FBG compared with that of the lower kimchi intake group ($P = .003$).

Serum triglyceride, total cholesterol, LDL-cholesterol, and HDL-cholesterol

As shown in Table 4, triglyceride concentrations of post-test was significantly reduced in both the low (−6.1 mg/dL, $P < .05$) and high group (−7.4 mg/dL, $P < .05$), but the differences between groups were not statistically significant. After the 7-day intervention trial in young healthy subjects, the mean of total cholesterol at post-test significantly declined in both low (−6.8 mg/dL, $P < .001$) and high intake (−8.9 mg/dL, $P < .001$). The high intake of kimchi resulted

TABLE 3. CHANGES IN FASTING BLOOD GLUCOSE CONCENTRATION AFTER 7 DAYS OF KIMCHI CONSUMPTION

	Low group (15 g/day)			*High group (210 g/day)*			
	Mean ± SD	*Change**	P-*value**	*Mean ± SD*	*Change**	P *value**	*Between group* P *value**
FBG (mg/dL)		−2.0 ± 4.7	.002		−5.3 ± 6.2	< .001	.003
Pre	78.7 ± 4.6			80.7 ± 5.4			
Post	76.5 ± 4.9			75.1 ± 6.0			

Values are mean ± SD.
*Change from baseline to 7 days.
FBG, fasting blood glucose.

Table 4. Comparison of Blood Lipid Profiles of the Subjects After 7 Days of Kimchi Consumption

	Low group (15 g/day)			*High group (210 g/day)*			
	Mean ± SD	*Change**	P *value**	*Mean ± SD*	*Change**	P *value**	*Between group* P *value**
TG (mg/dL)		−6.1 ± 18.4	*P* = .039		−7.4 ± 23.3	*P* = .046	*P* = .764
Pre	73.1 ± 29.0			75.2 ± 42.5			
Post	67.1 ± 29.2			67.7 ± 40.8			
TC (mg/dL)		−6.8 ± 11.4	*P* < .001		−8.9 ± 15.2	*P* < .001	*P* = .433
Pre	168.8 ± 25.3			174.4 ± 28.3			
Post	162.0 ± 27.5			165.5 ± 27.0			
LDL-C (mg/dL)		−3.4 ± 10.0	*P* = .025		−6.9 ± 13.2	*P* < .001	*P* = .147
Pre	95.6 ± 24.2			98.5 ± 24.7			
Post	92.3 ± 23.7			91.7 ± 23.7			
HDL-C (mg/dL)		−2.1 ± 4.8	*P* = .004		−2.7 ± 6.6	*P* = .008	*P* = .633
Pre	59.2 ± 10.0			63.3 ± 13.7			
Post	57.1 ± 10.1			60.7 ± 15.7			

Values are mean ± SD.
*Change from baseline to 7 days.
LDL, low density lipoprotein; HDL, high density lipoprotein; TG, total glucose; TC, total cholesterol.

in a greater effect on TC reduction, but the changes were not significant. There were also no significant differences in LDL- and HDL-cholesterol between the two groups. Although the subjects with high risk factors of total and LDL-cholesterol showed no significance before-after alteration of blood total and LDL-cholesterol, there were slight dose-dependent changes between the low- and high-intake groups. The Adult Treatment Panel III (ATP III) of the National Cholesterol Education Program issued an evidence-based set of guidelines on cholesterol management in 2001. According to ATP III guideline, total cholesterol and LDL-cholesterol level should be lower than 190 mg/dL and 130 mg/dL, respectively. Therefore, we divided the participants with normal and high risk blood levels of total cholesterol and LDL-cholesterol (Tables 5 and 6). In the kimchi-high intake group, the subjects with high levels of total cholesterol (≥190 mg/dL, $n = 12$) demonstrated significant decrease in total cholesterol (−22.7 mg/dL) compared that with normal level (<190 mg/dL, $n = 38$, −5.8 mg/dL). Also, greater LDL reduction (−14.7 mg/dL) was also observed in the high kimchi intake subjects with LDL concentrations over 130 mg/dL (Table 6), but without significance.

Total antioxidant status

There was a significant increase in the serum total antioxidant status in both groups ($P < .001$), and the changes were dose-dependent with a 5.17% increase in the low group and 7.47% in the high group (Table 7).

DISCUSSION

The present study demonstrated two important results as follows: First, the 7-day controlled intervention lowered FBG and improved serum lipid profiles, and total antioxidant status levels of subjects regardless the amount of kimchi intake. Second, high kimchi consumption exerted its beneficial effect on FBG and serum total cholesterol concentration, especially in hypercholesterolemic young adults.

The main purpose of our study was to investigate the effect of kimchi, while avoiding an influence of other diet components, on biological indicators of CVD risk of

Table 5. Comparison of Total Cholesterol Concentration of the Subjects Classified by Adult Treatment Panel III Guideline for Koreans After 7 Days of Kimchi Consumption

	TC < 190 (n = 38)				*TC ≥ 190 (n = 12)*			
	Mean ± SD (mg/dL)	*Change* (mg/dL)*	P *value**	*Between group* P *value**	*Mean ± SD (mg/dL)*	*Change* (mg/dL)*	P *value**	*Between group* P *value*
Low group (15 g/day)		−7.7 ± 10.9	*P* < .000	*P* = .180		−5.8 ± 15.3	*P* = .237	*P* = .032
Pre	159.3 ± 17.5				203.6 ± 16.1			
Post	151.6 ± 19.0				197.7 ± 20.2			
High group (210 g/day)		−4.4 ± 10.4[a]	*P* = .171			−22.7 ± 19.4[b]	*P* = .002	
Pre	159.9 ± 16.1				215.2 ± 16.9			
Post	157.1 ± 17.5				192.5 ± 32.5			

Values are mean ± SD.
*Changes in total cholesterol concentration.
[ab]Data in the row are significantly different at $P < .001$.

Table 6. Change in Low Density Lipoprotein–Cholesterol Concentration of the Subjects Classified by Adult Treatment Panel III Guideline After 7 Days of Kimchi Consumption

	LDL-C < 130 (n = 44)				*LDL-C ≥ 130 (n = 6)*			
	Mean ± SD (mg/dL)	*Change* (mg/dL)*	P *value**	*Between group* P *value**	*Mean ± SD (mg/dL)*	*Change* (mg/dL)*	P *value**	*Between group* P *value**
Low group (15 g/day)		− 2.9 ± 9.5	$P = .027$	$P = .740$		− 7.2 ± 14.6	$P = .332$	$P = .456$
Pre	90.9 ± 19.7				140.4 ± 9.1			
Post	87.3 ± 19.5				133.2 ± 13.1			
High group (210 g/day)		− 5.7 ± 12.5	$P = .035$			− 14.7 ± 16.7	$P = .085$	
Pre	90.6 ± 16.2				148.0 ± 15.9			
Post	86.1 ± 15.9				133.3 ± 27.5			

Values are mean ± SD.
*Change from baseline to 7 days.

subjects. Therefore, we designed an experimental trial in which prepared meals with different amount of kimchi were supplied to the subjects. As compared with previous diets before kimchi intervention study, fat intake ratio was reduced by 5.1% and 6.1% for the low and high group, respectively (Table 2). Furthermore, the diet used during the experimental period was planned by a dietitian and supplied regularly. These points demonstrated that the controlled diet had other favorable effects on serum glucose level and lipid profile in young health adults.

We performed the carefully controlled dietary intervention trial which resulted in the small, but clinically significant reductions in FBG between the low and high intake of kimchi consumption and total-cholesterol concentration in the hypercholesterolemic subjects when relatively high amounts of kimchi (210 g/day) were introduced into the diet. One of the most important aspects of the present study was that it maintained all dietary constituents at identical levels during the experimental period. Only the amount of kimchi was altered between groups and hence the significant changes in serum glucose between the two groups and total cholesterol in hypercholesterolemic subjects can be entirely attributed to the kimchi intake.

Epidemiological surveys have suggested that serum total cholesterol levels are strongly associated with CHD risk, a relationship that has been observed worldwide from many populations.[18,19] It is well known that serum LDL-C concentration and total cholesterol concentrations are highly correlated with CHD risk. Serum cholesterol concentration can be easily increased with foods rich in saturated fats or cholesterol. In addition, high cholesterol levels can be easily seen in pathological conditions such as DM, hypothyroidism, liver or kidney disease as well as from inherited disorders where lipoprotein is improperly metabolized or abnormally synthesized. Diminishing the serum cholesterol is an important strategy for ameliorating CHD risk in individuals. Most foods with heart healthy claims do not have evidence-based efficacy support from clinical trials. However, foods like soy, nuts, viscous fibers, and plant sterols are known to have serum cholesterol lowering effects and their effect on LDL-cholesterol reduction have been found to be even greater.[20]

If the ∼8%–10% reduction in total- and LDL-cholesterol is converted into reduction in absolute risk of coronary heart disease (CHD) or stroke using criteria set by a trial such as the MR FIT study,[19] CHD and stroke risk would be predicted to drop by up to 27% and 25%, respectively. It is of considerable importance that this trial has achieved such an improvement in profiles of healthy individuals, not only because this change represents prevention rather than treatment of CVD. Any nutritional strategy which can ensure prevention rather than cure must underpin current public health policies. We designed the study to see the lipid lowering effect of fermented kimchi in young adults with controlled diet. In the present study, dose-dependent decreasing trend in serum triglyceride, total cholesterol, LDL-cholesterol and FBG concentration were observed. In particular, kimchi intake in young subjects alleviated the LDL-cholesterol levels (low group: − 3.50%, high group: − 6.95%). Furthermore, as serum cholesterol level divided

Table 7. Total Antioxidant Status of the Subjects After 7 Days of Kimchi Consumption

	Low group (15 g/day)			*High group (210 g/day)*			
	Mean ± SD	*%Change*	P *value**	*Mean ± SD*	*%Change*	P *value**	*Between group* P *value**
TAS (mmol/L)		5.67 ± 6.05	$P < .001$		7.36 ± 7.32	$P < .001$	$P = .267$
Pre	1.74 ± 0.14			1.74 ± 0.14			
Post	1.83 ± 0.12			1.87 ± 0.14			

Values are mean ± SD. %Change = (Post − Pre)/Pre × 100.
*Change from baseline to 7 days.
TAS, total antioxidant status.

into risk and normal according to ATP III, high intake of kimchi exerted the further reductions in total cholesterol and LDL-cholesterol by −11.00% and −10.47%, respectively, compared with those of the low group. These results demonstrated that a greater intake of kimchi could alleviate the cholesterol-related risk factors in healthy subjects, especially in hypercholesterolemic subjects.

Increases in daily intake of fruit and vegetables have been associated with better plasma lipid profiles and lower blood pressure, demonstrating a protective effect against the risk of CVD. In a study of fruit and vegetable intake and risk of ischemic stroke, high consumption of cruciferous vegetables (e.g., broccoli, cabbage, cauliflower, brussel sprouts), green leafy vegetables, citrus fruits, and vitamin C-rich fruit and vegetables[15] resulted in the lowest risk. In follow-up studies by health professionals investigating the associations between food patterns and plasma lipids,[21,22] inverse correlations between a prudent pattern (high in vegetables, legumes, whole grains, fruit, oils, salad dressing, and fish) and total cholesterol ($r = -0.25$) and triglyceride ($r = -0.17$) were observed and positive correlations between a Western pattern (high in meat, butter, high-fat dairy products, refined grains, eggs, and French fries) and total cholesterol ($r = 0.18$) and triglyceride ($r = 0.10$) were found, although significance levels for these associations were not reported.

Numerous studies have reported on the lipid-lowering mechanisms of kimchi or its ingredients such as Chinese cabbage, hot red pepper, garlic, green leek, and ginger. β-sitosterol in Chinese cabbage, *S*-methlycysteinsulfoxide and *S*-allylcysteinsulfoxide in garlic, capsaicin in red pepper are known bioactive compounds present in kimchi ingredients responsible for lowering blood lipids.[23–25] β-Sitosterol, a phyto-cholesterol, competes with dietary cholesterol in the intestine for absorption.[23] Sulfur compounds in onion and garlic stimulate lipolysis by elevating the hormone secretion such as adrenalin and glucagon, or suppressing enzyme activities responsible for s cholesterol synthesis. Acetyl-CoA synthetase and/or 3-hydroxy-3-methyl-glutaryl CoA reductase activity was inhibited by allin or allicine.[24] Capsaicin stimulates the secretion of plasma cholesterol to extra-circulation as bile via elevating 7α-hydroxylase activity.[25] It also increases energy expenditure by regulating thyroid hormone secretion.[26] Additionally, lactic acid bacteria produced during the fermentation of kimchi are believed to contribute to the cholesterol lowering activity. *Lactobacillus acidophilus* usually detected in kimchi can bind the cholesterol in their cell wall besides decomposing the cholesterol for assimilation and de-conjugates the bile acids.[27] In our previous study, kimchi effectively attenuated plasma cholesterol levels in rats and rabbits fed high cholesterol diets.[28] In addition, hypercholesterolemic rabbits administered bioactive compound of kimchi, HDMPPA showed a drop in plasma cholesterol and LDL-cholesterol within 4 days of treatment.[9] These results supported our findings that kimchi supplementation to young adults for a short period could alleviate serum cholesterol concentration.

High FBG is a risk factor associated with type 2 diabetes and thus FBG levels became a significant predictor for hypercholesterolemia. In a 5-year follow-up study examining the risk factors of hypercholesterolemia, one third of participants with FBG levels greater than 100 mg/dL at baseline examination readily developed hypercholesterolemia. The association between non-insulin-dependent DM and increased triglyceride, LDL-cholesterol and decreased HDL-cholesterol levels are established as a fact.[29] Furthermore, results of a 22-year follow-up of healthy men showed that FBG values appeared to be an important independent predictor of cardiovascular death in nondiabetic apparently healthy middle-aged men. Therefore, to control the risk derived from the high blood cholesterol, FBG even among health population should be managed. In the present study, kimchi consumption significantly lowered the FBG concentration according to amount of kimchi intake. There are several considerations about the lowering effect of kimchi on FBG. Compared with energy and carbohydrate intake between pre- and post-test, these two factors showed no difference in the two groups. Furthermore, in a previous questionnaire for physical activity, 36% and 27% subjects in the low and high group answered ''no extra exercise'', respectively (data not shown). These data suggested that a relatively greater reduction of FBG or plasma lipids in the high group could be related with intake of kimchi.

Our study has some limitations. Our clinical trial was carried out only 1 week since all subjects should be stayed together to control the diet and physical activity to examine the effect of kimchi alone. Low and high kimchi intake group were used instead of having a no kimchi group as a control since Korean usually have some kimchi with each meal along with rice and other dishes. The subjects for the study are composed of young adults whose health status is relatively healthy thereby the benefit results observed in this study can be applicable to all generations with/without disease. Further clinical studies are needed to confirm benefits in individuals never exposed to the kimchi.

In conclusion, kimchi consumption could have health promoting effects in young adults including improving FBG, serum lipid profiles, and total antioxidant status, demonstrating that kimchi may be protective against lipid-related diseases.

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AUTHOR DISCLOSURE STATEMENT

No competing financial interests exist.

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