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Association between fried food consumption and hypertension in Korean adults

Yunjin Kang and Jihye Kim*

Department of Medical Nutrition, Graduate School of East-West Medical Science, Kyung Hee University, Yongin 446-701, Korea

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Abstract

The present study explored the relationships between fried food consumption and metabolic risk factors and hypertension in Korean adults. The study was based on the fifth Korean National Health and Nutrition Examination Survey between 2010 and 2011. A total of 9221 Korean adults aged ≥19 years were studied. Fried food consumption was assessed using a validated FFQ. Metabolic risk factors such as waist circumference, fasting plasma glucose (FPG), TAG, HDL-cholesterol and systolic and diastolic blood pressure (SBP and DBP) were measured. Hypertension was defined as SBP ≥140 mmHg, DBP ≥90 mmHg or current use of antihypertensive medication. Adjusted OR for elevated blood pressure significantly increased in men (OR 1·62; 95 % CI 1·11, 2·37; P_{trend} = 0·0447) and women (OR 2·20; 95 % CI 1·21, 4·00; P_{trend} = 0·0403) with a greater than twice a week consumption of fried food compared with those who rarely consumed fried food. However, fried food consumption was not associated with other metabolic risk factors (abdominal obesity, high FPG, hypertriacylglycerolaemia, low HDL-cholesterol and the metabolic syndrome). The adjusted OR for hypertension increased by 2·4-fold in women (OR 2·37; 95 % CI 1·19, 4·72; P_{trend} = 0·0272) with a greater than twice a week fried food consumption compared with those who rarely consumed it. No significant association was found between fried food consumption and hypertension in men. This study suggests that frequent fried food consumption is associated with hypertension in Korean women. Further studies are needed to investigate the effect of different types of fried foods on hypertension.

Key words: Fried food consumption: Hypertension: Blood pressure: Korean adults

Hypertension is one of the major risk factors for CVD. It is an important global public health issue in Korea and worldwide[1]. According to data from the Korean National Health and Nutrition Examination Survey (KNHANES), hypertension is steadily increasing in Korean adults. The prevalence of hypertension increased from 28·9 % for men and 25·5 % for women between 2007 and 2009 to 32·4 % for men and 28·4 % for women between 2010 and 2012[2]. Previous studies have reported associations between some nutrients, food and food groups and blood pressure (BP)[3–5]. In particular, a high-fat diet including *trans*-fats and SFA was associated with increased BP[6].

Frying is a common and popular cooking method in Western countries. Frying involves changes in flavour, taste and colour[7]. Because of the absorption of fat, frying imparts crispiness and flavour and improves the palatability of foods[8]. However, fried food consumption has been reported to be associated with metabolic risk factors[9–11] and the metabolic syndrome (MetS)[12]. Frequent fried food consumption is associated with larger waist circumference (WC)[9], elevated BP[10], higher LDL-cholesterol level[11] and lower HDL-cholesterol level[9]. Although fried food intake has been found to be positively associated with metabolic risk factors including BP, information on the relationship between fried food consumption and hypertension is very limited. To the best of our knowledge, only one study has reported that fried food consumption was positively associated with incident hypertension in a Spanish population[13]. However, the relationship between fried food consumption and hypertension has not been investigated in Asian countries, although frying food is also a common practice in Asia.

The Korean diet has recently undergone rapid changes. In particular, the consumption of Western-style food including fried food is rapidly increasing among Koreans[14]. However, the associations between fried food intake and metabolic risk factors and hypertension have not been investigated in a Korean population. Therefore, the aim of this study was to investigate the associations between fried food consumption, metabolic risk factors and hypertension in Korean adults, using nationally representative survey data.

Abbreviations: BP, blood pressure; DBP, diastolic blood pressure; DDS, dietary diversity score; FPG, fasting plasma glucose; MetS, metabolic syndrome; SBP, systolic blood pressure; TFA, *trans*-fatty acids; WC, waist circumference.

* **Corresponding author:** J. Kim, fax +82 31 204 8119, email kjhye@khu.ac.kr

Methods

Study population

The KNHANES is a national cross-sectional survey performed by the Korea Centers for Disease Control and Prevention (CDC) using a multistage, clustered, stratified and rolling sampling method. The survey contains a health interview, health examination and nutrition survey. We analysed the data in the KNHANES from 2010 to 2011, including 17 476 (8958 in 2010 and 8518 in 2011) participants. A total of 13 306 adults aged 19 years and older were selected for the present study. We excluded 4085 adults who reported unusual energy intakes (<3347·2 or >16 736 kJ/d (<800 or >4000 kcal/d) for men and <2092 or >14 644 kJ/d (<500 or >3500 kcal/d) for women) or with insufficient data in the socio-economic, anthropometric or biochemical information. As a result, 9221 adults (3634 men and 5587 women) were eligible for the analysis. The study was approved by the Korea CDC Institutional Review Board.

Dietary intake assessment

Fried food consumption was measured using a validated FFQ[15]. The 109-item FFQ was administered twice, approximately 9 months apart. Four seasonal 3-d dietary records were used as a reference method. The average correlation coefficients measuring reproducibility were 0·54 for nutrients and 0·57 for food groups. The mean correlation coefficient measuring validity was 0·40 for all nutrients between the first FFQ and the dietary record. The FFQ was conducted through face-to-face interviews by trained dietitians. Participants were asked about usual frequencies of fried food consumption over the previous year as follows: 'How often did you eat fried food during the past year?'. We obtained data on usual food consumption during the past year on a daily, weekly or monthly basis. Answer options were presented in ten categories and classified into four groups: (1) rarely: none to 6–11 times/year; (2) ≥1/month: 1 or 2–3 time(s)/month; (3) 1/week: 1 time/week; and (4) ≥2/week: 2–6 times/week or 1–3 time(s)/d. The FFQ included all fried food regardless of food group. According to 24-h recall, fried meat including chicken, pork and beef accounted for 45 % of all fried food and fried vegetable including onion, potato and pepper accounted for 31 % of all fried foods. Fish and shellfish accounted for 12 % of all fried food. The dietary intakes used to calculate nutrient intakes were determined using the 24-h recall method. Nutrient intakes were estimated from the food composition table of the Rural Development Administration in combination with the nutrient database of the Korea Health and Industry of Development Institute[16].

Measurements

Height and body weight were measured as a part of the health examination study[17]. BMI was calculated as weight (kg) divided by height squared (m^2). WC was measured by trained researchers as a part of the health examination study. WC was measured to the nearest 0·1 cm at the narrowest point between the lowest rib and the uppermost lateral border of the right iliac crest. BP was measured with a Baumanometer mercury sphygmomanometer (WA Baum) after subjects had rested for 5 min in a sitting position. Systolic and diastolic blood pressures (SBP and DBP) were measured at phase I and V Korotkoff sounds[18], respectively. Three readings of SBP and DBP were recorded, and the average of the last two readings was used for analysis. Blood samples were measured in the morning after an overnight fast. Fasting plasma glucose (FPG), TAG and HDL-cholesterol were measured enzymatically using a Hitachi automatic analyzer 7600 (Hitachi) in central, certified laboratories. All biochemical analyses were carried out within 2 h of blood sampling.

Definition of the metabolic syndrome and hypertension

The definition of the MetS came from the joint interim statement issued by the International Diabetes Federation and the American Heart Association/National Heart, Lung, and Blood Institute as ≥3 of any of the following: abdominal obesity (WC >90 cm for men or >80 cm for women, as previously described); hyperglycaemia (FPG ≥100 mg/dl (5·5 mmol/l)) or current use of insulin or oral hypoglycaemia medication or a physician's diagnosis; hypertriacylglycerolaemia ≥150 mg/dl (1·7 mmol/l); low HDL-cholesterol <40 mg/dl (1·04 mmol/l) in men or <50 mg/dl (1·30 mmol/l) in women; and elevated BP (SBP/DBP ≥130/85 mmHg) or the use of antihypertensive medication[19]. Hypertension was defined as SBP ≥140 mmHg, DBP ≥90 mmHg or current use of antihypertensive medication[20].

Covariates

Demographic characteristics, socio-economic status and lifestyle factors were obtained using in-person interviews by a trained researcher and a self-administered questionnaire. Income level was categorised into three groups: low (below average); medium (average); and high (above average). Education level was divided into three groups: ≤6 years (elementary school level); 6–12 years (middle or high school level); and ≥12 years (college level). Smoking status was classified as non-smoker, former smoker or current smoker. Alcohol intake was categorised into non-drinker, moderate drinker (<2 times/week) and heavy drinker (≥2 times/week)[21]. The regular physical activity group was classified into hard exercise for ≥20 min at a time ≥5 d/week, moderate exercise for ≥30 min at a time ≥5 d/week or walking for ≥30 min at a time ≥5 d/week. Chronic diseases such as CVD, type 2 diabetes and cancer were assessed by the question – Have you been diagnosed with a disease in the last year? (yes/no). Diet quality was assessed using a dietary diversity score (DDS). DDS was determined on the basis of foods the subjects consumed from the various five basic food groups (cereal, meat, dairy products, vegetable and fruit). When a subject consumed the designated amount of foods from a certain food group, one point was given. A maximum of five points was given when one ate the designated amount of foods from all five basic food groups[22].

Statistical analyses

All data were analysed by PROC SURVEY using SAS version 9.3 (SAS Institute). To reflect national population estimates, sample

weights were applied in all analyses. The Rao–Scott's χ^2 test was used for categorical variables with the PROC SURVEYFREQ procedure. The PROC SURVEYMEANS procedure was used for means with their standard errors of continuous variables. The PROC SURVEYREG procedure was used to compare differences according to sex and frequency of fried food consumption. Interaction between sex and the frequency of fried food consumption was tested using likelihood ratio tests between the fully adjusted models and the same model, but by introducing the interaction product term.

A multivariable-adjusted logistic regression analysis was conducted to determine OR and 95 % CI for components of the MetS and hypertension across levels of frequency of fried food consumption using PROC SURVEYLOGISTIC. For all the analyses, an unadjusted univariate model, and an age- and sex-adjusted model (model 1) and a multivariable model were used. Model 2 was adjusted for age, sex, BMI, income level, educational level, smoking status, physical activity, alcohol intake, energy intake, Na intake, DDS and disease (cancer, CVD or diabetes). For the selection of potential confounders in the multivariable model, and as currently recommended[23], the previously published scientific literature, including our own results based on the cross-sectional study regarding potential risk factors for the MetS or hypertension, was taken into account, avoiding exclusively the statistical approach with the *P* value, the step-wise procedures or the changes in point estimates after adjusting for potential confounders. All *P* values <0·05 were considered to be statistically significant.

Results

Characteristics of subjects

Characteristics of study subjects are shown in Table 1. Women were older compared with men ($P=0·0140$). Men were more likely to be educated, current smokers, heavy alcohol drinkers and regular exercisers and to have higher energy intake and Na intake and a lower DDS compared with women. Men had

Table 1. Characteristics of the study subjects
(Numbers and percentages; mean values with their standard errors)

	Men (*n* 3634)		Women (*n* 5587)		
	n	%	*n*	%	*P**
Age (years)	44·3	0·4	45·3	0·4	0·0140
Income (%)					0·5452
Low	832	25·6	1354	27·0	
Medium	1884	51·1	2824	50·1	
High	918	23·3	1409	23·0	
Educational level (%)					<0·0001
≤6 years	649	11·3	1694	24·3	
6–12 years	1733	50·8	2368	45·4	
≥12 years	1252	37·8	1525	30·3	
Smoking status (%)					<0·0001
Never	669	20·4	5013	87·5	
Former	1561	34·5	314	6·7	
Current	1404	45·1	260	5·7	
Alcohol intake (%)					<0·0001
Never	584	12·7	2002	31·0	
<2 times/week	1692	52·3	3136	59·7	
≥2 times/week	1358	35·0	449	9·3	
Physical activity (%)					<0·0001
Regular	1852	52·5	2512	46·8	
MetS (%)	1115	26·4	1377	20·5	<0·0001
Hypertension (%)	1258	26·2	1507	21·2	<0·0001
Disease (%)	576	10·7	681	10·0	0·4099
	Mean	SE	Mean	SE	*P*†
Energy intake (g)	2343·6	16·2	1705·5	11·2	<0·0001
Na intake (g)	5953·8	70·8	4214·0	50·3	<0·0001
DDS	3·8	0·01	3·9	0·01	<0·0001
BMI (kg/m²)	24·0	0·1	23·2	0·1	<0·0001
WC (cm)	84·0	0·2	77·7	0·2	<0·0001
SBP (mmHg)	118·9	0·4	114·5	0·4	<0·0001
DBP (mmHg)	77·5	0·3	72·5	0·2	<0·0001
FPG (mmol/l)	5·5	0·03	5·2	0·02	<0·0001
TAG (mmol/l)	1·7	0·03	1·2	0·02	<0·0001
HDL-cholesterol (mmol/l)	1·2	0·01	1·3	0·01	<0·0001

Disease, cancer, CVD and diabetes; MetS, metabolic syndrome; DDS, dietary diversity score; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; FPG, fasting plasma glucose.
* *P* value was determined by χ^2 test.
† *P* value was determined by *t* test.

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Table 2. Characteristics of the study subjects according to frequency of fried food consumption (Numbers and percentages; mean values with their standard errors)

	Rarely* (*n* 3973)		≥1/month (*n* 3802)		1/week (*n* 942)		≥2/week (*n* 504)		
	n	%	*n*	%	*n*	%	*n*	%	*P*†
Age (years)	54·5[a]	0·4	41·9[b]	0·4	36·3[c]	0·5	32·0[d]	0·5	<0·0001
Sex (%)									<0·0001
Men	1428	41·5	1519	48·5	446	57·9	241	59·8	
Women	2545	58·5	2283	51·5	496	42·1	263	40·2	
Income (%)									0·0260
Low	1101	29·7	808	24·9	175	24·4	102	22·8	
Medium	1965	48·9	2004	51·6	474	50·7	265	52·2	
High	907	21·4	990	23·6	293	24·9	137	25·0	
Educational level (%)									<0·0001
≤6 years	1701	35·4	569	11·3	64	5·3	9	0·9	
6–12 years	1623	45·1	1789	48·7	430	48·3	259	56·6	
≥12 years	649	19·5	1444	40·1	448	46·4	236	42·5	
Smoking status (%)									<0·0001
Never	2541	58·6	2350	55·9	516	48·0	275	48·0	
Former	845	21·8	755	19·1	186	18·9	89	20·2	
Current	587	19·6	697	25·0	240	33·1	140	31·9	
Alcohol intake (%)									<0·0001
Never	1471	31·0	870	19·8	166	13·7	79	10·7	
<2 times/week	1775	47·7	2217	60·0	554	63·3	282	59·5	
≥2 times/week	727	21·3	715	20·2	222	22·9	143	29·8	
Physical activity (%)									0·0193
Regular	1872	48·5	1761	48·3	465	52·9	266	55·7	
Disease (%)	773	16·1	411	8·8	57	4·7	16	3·0	<0·0001
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	*P*‡
Energy intake (g)	1850·8[a]	16·6	2033·5[b]	16·0	2251·6[c]	33·0	2279·1[c]	46·7	<0·0001
Na intake (g)	4743·1[a]	75·0	5105·0[b]	67·2	5521·5[c]	132·5	5348·6[bc]	159·4	<0·0001
DDS	3·8[a]	0·02	3·9[b]	0·01	3·9[b,c]	0·03	3·8[b,d]	0·04	<0·0001
BMI (kg/m²)	23·7[a]	0·1	23·5[b]	0·1	23·5[a,b]	0·1	23·7[a,b]	0·2	0·1133
WC (cm)	81·8[a]	0·2	80·1[b]	0·3	80·3[b]	0·4	80·1[b]	0·7	<0·0001
SBP (mmHg)	121·7[a]	0·5	114·5[b]	0·4	113·1[c]	0·6	111·8[c]	0·6	<0·0001
DBP (mmHg)	75·7[a]	0·3	74·5[b]	0·3	74·3[b]	0·5	74·3[b]	0·5	0·0014
FPG (mmol/l)	5·5[a]	0·03	5·3[b]	0·02	5·2[c]	0·04	5·2[b,c]	0·09	<0·0001
TAG (mmol/l)	1·5[a]	0·02	1·4[b]	0·03	1·5[a,b]	0·05	1·5[a,b]	0·09	0·0060
HDL-cholesterol (mmol/l)	1·2[a]	0·01	1·3[b]	0·01	1·3[b]	0·01	1·3[b]	0·02	0·0004

Disease, cancer, CVD and diabetes; DDS, dietary diversity score; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; FPG, fasting plasma glucose.
[a,b,c,d] Mean values within a row with unlike superscript letters were significantly different ($P < 0·05$; ANOVA).
* Rarely: rarely or 6–11/year, ≥1/month: 1–3/month, 1/week: 1/week, ≥2/week: 2–6/week or 1–3/d.
† *P* value was determined by χ^2 test.
‡ *P* value was determined by ANOVA and Tukey's test for *post hoc* analysis.

higher BMI, WC, SBP, DBP, FPG and TAG compared with women, whereas HDL-cholesterol was significantly lower in men than in women ($P < 0·0001$). The prevalence of the MetS and hypertension were significantly higher in men than in women ($P < 0·0001$).

Characteristics of subjects according to frequency of fried food consumption

Characteristics of subjects according to frequency of fried food consumption are shown in Table 2. Subjects in the highest category of fried food consumption (≥2/week) were younger and more likely to be men compared with those in the lowest category (rarely). Subjects in the highest category of fried food consumption were more likely to have a higher income, higher educational level, be non-smokers, alcohol drinkers, exercise regularly and to have higher Na intake. In terms of health-related variables, subjects in the highest category of fried food consumption were more likely to have lower SBP, DBP and FPG and higher HDL-cholesterol level.

Associations of frequency of fried food consumption with metabolic risk factors and hypertension

Adjusted OR and 95 % CI for components of the MetS according to frequency of fried food consumption are showed in Table 3. The adjusted OR of elevated BP increased by 1·6-fold in men ($P_{trend} = 0·0447$) and by 2·2-fold in women ($P_{trend} = 0·0403$) who reported eating fried food more than twice a week compared with those who reported rarely consuming fried food after adjusting for potential risk factors of age, BMI, income level, education level, smoking status, alcohol intake, physical activity, total energy intake, Na intake, DDS and the presence of chronic disease. However, fried food consumption was not associated with other metabolic risk factors. Adjusted OR and 95 % CI for hypertension according to frequency of fried food

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Table 3. The metabolic risk factors and hypertension according to fried food consumption (Odds ratios and 95 % confidence intervals)

	Rarely*	≥1/month		1/week		≥2/week			
	Ref.	0	95 % CI	OR	95 % CI	OR	95 % CI	*P*	*P*†
Total‡									
Abdominal obesity§	1·0	0·91	0·77, 1·07	0·74	0·58, 0·96	0·65	0·47, 0·88	0·7307	0·0157
High fasting glucose	1·0	1·05	0·91, 1·22	1·11	0·86, 1·44	0·92	0·64, 1·33	0·6742	0·1288
Hypertriacylglycerolaemia	1·0	1·08	0·94, 1·25	0·89	0·72, 1·10	1·22	0·92, 1·62	0·1611	0·7533
Low HDL-cholesterol	1·0	1·06	0·92, 1·22	0·96	0·77, 1·20	0·85	0·66, 1·10	0·2937	0·9311
Elevated BP‖	1·0	1·23	1·06, 1 44	1·16	0·91, 1·49	1·56	1·14, 2·15	0·0126	<0·0001
MetS	1·0	1·16	0·99, 1·36	0·93	0·71, 1·23	0·98	0·65, 1·49	0·2368	0·2048
Men¶									
Abdominal obesity**	1·0	0·92	0·70, 1·21	0·83	0·56, 1·24	0·65	0·42, 1·02	0·2733	
High fasting glucose	1·0	1·15	0·92, 1·44	0·97	0·70, 1·36	1·07	0·64, 1·80	0·5589	
Hypertriacylglycerolaemia	1·0	1·18	0·95, 1·46	1·01	0·74, 1·37	1·40	0·96, 2·05	0·2056	
Low HDL-cholesterol	1·0	1·06	0·85, 1·33	0·394	0·67, 1·31	0·78	0·51, 1·18	0·4384	
Elevated BP‖	1·0	1·27	1·01, 1·59	1·12	0·81, 1 56	1·62	1·11, 2·37	0·0447	
MetS	1·0	1·23	0·97, 1·56	0·94	0·63, 1·38	1·06	0·63, 1·79	0·2430	
Women¶									
Abdominal obesity**	1·0	0·84	0·70, 1·02	0·61	0·44, 0·84	0·75	0·44, 1·27	0·0214	
High fasting glucose	1·0	0·95	0·76, 1·19	1·49	0·98, 2·27	0·67	0·42, 1·09	0·0551	
Hypertriacylglycerolaemia	1·0	0·92	0·74, 1·16	0·70	0·48, 1·03	1·07	0·60, 1·89	0·3131	
Low HDL-cholesterol	1·0	1·06	0·89, 1·26	0·98	0·75, 1·28	0·97	0·71, 1·33	0·8219	
Elevated BP‖	1·0	1·07	0·86, 1 33	1·42	0·94, 2·15	2·20	1·21, 4·00	0·0403	
MetS	1·0	1·02	0·79, 1·32	0·99	0·62, 1·60	0·97	0·49, 1·90	0·9983	

Ref., referent values; BP, blood pressure; MetS, metabolic syndrome.
* Rarely: rarely or 6–1/year, ≥1/month: 1–3/month, 1/week: 1/week, ≥2/week: 2–6/week or 1–3/d.
† *P* for interaction between sex.
‡ Adjusted for age, sex, BMI, income level, education level, smoking status, alcohol consumption, physical activity, energy intake, dietary diversity score and disease.
§ Adjusted for model‡ excluding BMI.
‖ Adjusted for model‡,¶ plus Na intake.
¶ Adjusted for age, BMI, income level, education level, smoking status, alcohol consumption, physical activity, energy intake, dietary diversity score and disease.
** Adjusted for model¶ excluding BMI.

Table 4. Blood pressure and hypertension according to frequency of fried food consumption (Odds ratios and 95 % confidence intervals)

	Rarely	≥1/month		1/week		≥2/week			
	Ref.	OR	95 % CI	OR	95 % CI	OR	95% CI	*P*	*P**
Hypertension									
Unadjusted	1·0	2·55	2·21, 2·94	3·53	2·75, 4·55	5·67	3·99, 8·06	<0·0001	<0·0001
Model 1†	1·0	1·14	0·97, 1·34	1·03	0·79, 1·35	1·18	0·78, 1·79	0·4327	<0·0001
Model 2‡	1·0	1·18	0·99, 1·39	1·11	0·84, 1·46	1·41	0·93, 2·14	0·1799	<0·0001
Men									
Unadjusted	1·0	2·00	1·61, 2·49	2·55	1·84, 3·52	3·78	2·48, 5·74	<0·0001	
Model 1§	1·0	1·09	0·86, 1·38	0·94	0·67, 1·30	1·16	0·73, 1·83	0·6788	
Model 2‖	1·0	1·13	0·89, 1·44	0·99	0·70, 1·39	1·39	0·87, 2·23	0·4243	
Women									
Unadjusted	1·0	3·43	2·88, 4·07	7·54	5·06, 11·25	23·17	11·87, 45·23	<0·0001	
Model 1§	1·0	1·10	0·89, 1·37	1·67	1·06, 2·62	2·27	1·16, 4·42	0·0219	
Model 2‖	1·0	1·14	0·91, 1·43	1·62	1·01, 2·58	2·37	1·19, 4·72	0·0272	

Ref., referent values.
* *P* for interaction between sex.
† Adjusted for age and sex.
‡ Model 1 + BMI, income level, educational level, smoking status, alcohol consumption, physical activity, energy intake, Na intake, dietary diversity score and disease.
§ Adjusted for age.
‖ Model 2 + BMI, income level, educational level, smoking status, alcohol consumption, physical activity, energy intake, Na intake, dietary diversity score and disease.

consumption are shown in Table 4. For women, the OR of hypertension showed a 2·4-fold increase in those reporting fried food consumption of more than twice a week compared with those who reported rarely eating fried food after adjusting for potential risk factors ($P_{trend} = 0·0272$) and potential confounders. No significant association was found between the frequency of fried food consumption and hypertension in men.

Discussion

This study found that fried food consumption was strongly associated with hypertension among Korean women. For men, the OR of elevated BP showed a 1·6-fold increase after adjusting for potential risk factors of age, BMI, income level, education level, smoking status, alcohol intake, physical activity, total

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energy intake, Na intake, DDS and the presence of chronic disease for those reporting a fried food consumption more than twice a week compared with those who reported rarely eating fried foods. Women also showed a 2·2-fold increase in the OR of elevated BP for those reporting fried food consumption more than twice a week compared with those who reported rarely eating fried food after adjusting for potential risk factors. In addition, only women showed a 2·4-fold increase in the OR of hypertension among those who reported eating fried food more than twice a week compared with those who reported rarely eating fried food after adjusting for potential risk factors.

Our findings are similar to results from a previous study by Sayon *et al.*[10] involving 8289 Spanish men and women aged 20–90 years, which reported a positive association between fried food consumption and the prevalence of elevated BP. Sayon *et al.*[10] found that subjects in the upper category of fried food consumption had a 1·16-fold higher risk of elevated BP compared with those in the lower category of fried food consumption. Among 5037 US adults aged 65 years and older, participants consuming fried fish more than once a week tended to have an increased risk of elevated BP compared with those consuming fried fish less than once a month, suggesting that fried food intake is related to higher mean BP[24]. A Mediterranean cohort study on 13 679 Spanish university graduates found that those who consumed fried foods more than four times a week had a 1·21-fold greater risk of hypertension compared with those eating fried foods less than twice a week[13].

Several reports have demonstrated the mechanisms behind the relationship between fried food consumption and elevated BP or hypertension. The process of frying involves various physicochemical changes and reactions including oxidation, pyrolysis, polymerisation, hydrolysis and isomerisation. A multitude of products formed by frying, such as polar compounds resulting from oils and fats heated at high temperatures, may influence BP[25,26]. In particular, a considerable amount of *trans*-fatty acids (TFA) is produced during the process of frying[26,27]. TFA elevate LDL-cholesterol level and reduce HDL-cholesterol level. Increased LDL-cholesterol increases the expression of angiotensin II (Ang II) type 1 receptors, which explains the increased sensitivity to Ang II in vascular smooth muscle cells[28]. Ang II leads to contraction of blood vessels and increases BP by inducing excretion of water and salt from the kidney[29]. In this way, TFA contribute to elevated BP. In Iranian women aged 40–60 years, a higher intake of TFA was associated with hypertension in a cross-sectional study[30]. A randomised controlled study reported that higher intakes of TFA and SFA were associated with increased risk of hypertension in middle-aged and older women[31].

In this study, there were no associations between fried food and other metabolic risk factors – such as abdominal obesity, FPG and lipid level – which are not consistent with some other studies[32,33]. This may be due to differences in the frequency of fried food consumption of subjects, the type of food group and the cooking method among studies. The subjects from our study may consume less fried food compared with other population[32,33]. Our study compared the Korean adults consuming fried food more than twice a week with those consuming it rarely, whereas the previous study showed that US adults consuming fried food more than four times a week or seven times a week had higher risk of type 2 diabetes in comparison with those consuming it rarely[33]. More frequent consumption of fried food may be associated with blood glucose. The type of food group might contribute to the inconsistent results. According to the data from 24-h recall, fried meat (45 %), vegetables (31 %), fish (12 %) and seaweed (8 %) were the four groups of fried food most frequently consumed by Korean adults, whereas fried meat, fish, potatoes and eggs were the four groups of fried food most frequently consumed by Spanish adults, with 75 % of subjects consuming each of those groups of food reporting a positive association between fried meat, fish and eggs intake and general obesity/central obesity[32]. Therefore, high consumption of plant food groups with less energy such as vegetable and seaweed in Korean population might have attenuated the relationship between fried food and abdominal obesity. Furthermore, cooking method – deep-frying or pan-frying – could have affected the relationship between fried food intake and metabolic risk factors. The frying method have different effects on the absorption of fat depending on the food, the oil used and the frying conditions[34]. However, this study could not distinguish between the two frying methods.

Interestingly, the present study showed an association between fried food consumption and hypertension in women only. It has been suggested that there are sex differences in the relationship between hypertension and its risk factors. Risk factors for hypertension such as renin–angiotensin system, sex hormones and increased immune inflammatory factors may have a greater impact on women than on men[35]. The responses to a stimulation of renin–angiotensin system were different in men and in women[36]. Likewise, women may be more sensitive compared with men to the relationship between diet and hypertension. The effect of diet or nutrients on BP may be greater in women than in men. For example, the reduction in BP with a diet of reduced Na and K supplementation was greater in women than in men[35]. Abramson *et al.*[37] reported that a modified-lifestyle approach involving a healthy diet was effective in mitigating risk factors for hypertension in women. Additionally, hypertension may be more difficult to manage in women than in men. A recent study on patients with hypertension documented that women were less likely to have BP control compared with men, although there were no differences in the use of BP medication or initiation of a new therapy for patients with uncontrolled hypertension, suggesting that the sex-based differences in BP treatment are necessary[38]. Besides, there are many different pathophysiological and social reasons why the results may have been only significant in women – which researchers are unable to specifically determine in the present study – but, that regardless, the results suggest that reducing fried food intake may be one method to decrease risk for hypertension in women.

The present study has several limitations. First, the results are not able to verify a causal relationship between fried food consumption and hypertension, because the study was cross-sectional in design. There is a possibility that subjects with hypertension might change their lifestyle such as diet and

physical activity. Second, we did not investigate in detail the type of fat or oil used for frying. In spite of these limitations, to the best of our knowledge, this is the first study to reveal associations among fried food consumption and hypertension and metabolic risk factors in a Korean population using data from a large nationally representative sample.

In conclusion, frequent consumption of fried food more than twice a week was associated with hypertension after adjusting for potential confounders in Korean women. According to this result, we suggest reducing fried food consumption and changing cooking methods to broiling, steaming and boiling. Less frequent consumption of fried foods and modifying cooking methods may help decrease elevated BP and reduce the risk of hypertension. A study on the effect of fat or oil type on health outcome and its underlying mechanism requires a better understanding of the associations between fried food consumption and chronic diseases in further studies.

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