British Journal of Nutrition (2014), **112**, 238–247 doi:10.1017/S0007114514000683

Red meat consumption is associated with an increased overall cancer risk: a prospective cohort study in Korea

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(Submitted 8 August 2013 – Final revision received 27 February 2014 – Accepted 3 March 2014 – First published online 28 April 2014)

Abstract

Cancer is a leading cause of death, and the dietary pattern in Korea is changing rapidly from a traditional Korean diet to a Westernised diet. In the present study, we investigated the effects of dietary factors on cancer risk with a prospective cohort study. Among 26 815 individuals who participated in cancer screening examinations from September 2004 to December 2008, 8024 subjects who completed a self-administered questionnaire concerning demographic and lifestyle factors, and a 3 d food record were selected. As of September 2013, 387 cancer cases were identified from the National Cancer Registry System, and the remaining individuals were included in the control group. The hazard ratio (HR) of cancer for the subjects older than or equal to 50 years of age was higher (HR 1·80, 95 % CI 1·41, 2·31; $P<0·0001$) than that for the other subjects. Red meat consumption, Na intake and obesity (BMI $\geq 25\,kg/m^2$) were positively associated with overall cancer incidence in men (HR 1·41, 95 % CI 1·02, 1·94; $P=0·0382$), gastric cancer (HR 2·34, 95 % CI 1·06, 5·19; $P=0·0365$) and thyroid cancer (HR 1·56, 95 % CI 1·05, 2·31; $P=0·0270$), respectively. Participants who had at least three dietary risk factors among the high intakes of red meat and Na, low intakes of vegetables and fruits, and obesity suggested by the World Cancer Research Fund/American Institute for Cancer Research at baseline tended to have a higher risk of cancer than the others (HR 1·26, 95 % CI 0·99, 1·60; $P=0·0653$). In summary, high intakes of red meat and Na were significant risk factors of cancer among Koreans.

Key words: **Cancer risk: Red meat: Sodium: Prospective cohort studies**

In Korea, cancer has been the leading cause of death since 1983, and the overall incidence rate has increased by 3·3 % per year (1·5 % in males and 5·3 % in females) from 1999 to 2010[1,2]. The incidence rates of prostate, breast and colorectal cancers have increased, whereas the rates of cervical uterine and liver cancers have decreased[2]. Many epidemiological studies have suggested that the risk of these cancers is associated with Westernised lifestyles[3–6].

According to the report by 2007 World Cancer Research Fund/American Institute for Cancer Research (WCRF/AICR), lifestyle factors such as diet, physical activity, alcohol consumption and cigarette smoking are the major risk factors for cancer[3]. Dietary risk factors, including high intakes of red meat and Na, low intakes of vegetables and fruits, and obesity, have been thought to account for approximately 30 % of cancer incidence in Western countries[7–24].

Korea has experienced a rapid and unique nutrition transition due to rapid economic growth and the introduction of Western culture over the last several decades[25–27].

The dietary pattern has shifted from a traditional Korean diet that is mostly based on rice and vegetables to a Westernised diet composed of mainly meat and their products[25–29].

Abbreviations: AICR, American Institute for Cancer Research; HR, hazard ratio; WCRF, World Cancer Research Fund.

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British Journal of Nutrition

Although intakes of fruits and vegetables among Koreans have been increasing, intake of salty fermented vegetables including kimchi remains to be high[30].

However, most epidemiological studies about the associations between dietary factors and cancer risk among Koreans are restricted to case–control study designs or specific cancer sites or selected regions or several nutrients[15,16,31–34]. Scientific evidence for the association between dietary factors and cancer risk among Koreans should be derived from prospective cohort studies or clinical trials to develop dietary guidelines for cancer prevention, because the epidemiological characteristics of cancer risk factors among Koreans may not be the same as in the people of Western societies.

Therefore, the present study was designed to investigate the association between dietary factors and cancer risk among Koreans using the data from the Cancer Screening Examination Cohort of the National Cancer Center of Korea.

Experimental methods

Study design and population

Of the 26 815 individuals who participated in the Cancer Screening Examination Cohort of the National Cancer Center of Korea from 1 September 2004 to 31 December 2008, 8179 participants who completed a self-administered questionnaire concerning demographic factors, medical history and behavioural factors, and a 3 d food record were selected for the present study. The details of the study population are shown in Fig. 1.

We excluded the participants with any history of cancer at baseline (*n* 79) or who reported an implausible daily energy intake (<2929 or >20 920 kJ (<700 or >5000 kcal); *n* 29). Cancer incidence among all participants after baseline was confirmed using the Korean Central Cancer Registry and/or the Electronic Medical Record of the National Cancer Center. As of 24 September 2013, 387 subjects were identified as cancer patients according to the International Classification of Diseases-10 Codes C00–C99, with the exception of Code D (*n* 47), and the remaining were assigned to the control group (*n* 7637)[35]. The number of subjects included in the final analysis was 8024.

Written informed consent was obtained from all subjects, and the study protocol was approved by the Institutional Review Board of the National Cancer Center (NCCNCS-09-274).

Dietary and lifestyle data collection

All participants were asked to complete a self-administered questionnaire concerning their demographic factors (e.g. age, education, occupation, household income and marital status), behavioural factors (e.g. cigarette smoking, alcohol intake and regular exercise) and personal medical history.

For each subject, height and weight were measured using InBody 3.0 (Biospace), and BMI was calculated by dividing weight (kg) by the square of height (m^2). According to the criteria of the WHO Asia-Pacific Region, those subjects with a BMI ≥25 kg/m^2 were classified as obese[36,37].

Data for sex, age, height and weight, and cancer site and diagnosis time were ascertained using the clinical database of the Korean National Cancer Center.

Dietary intake data were obtained from a 3 d food record. The participants were asked to complete a food record for 2 weekdays and 1 weekend day within a week. To increase

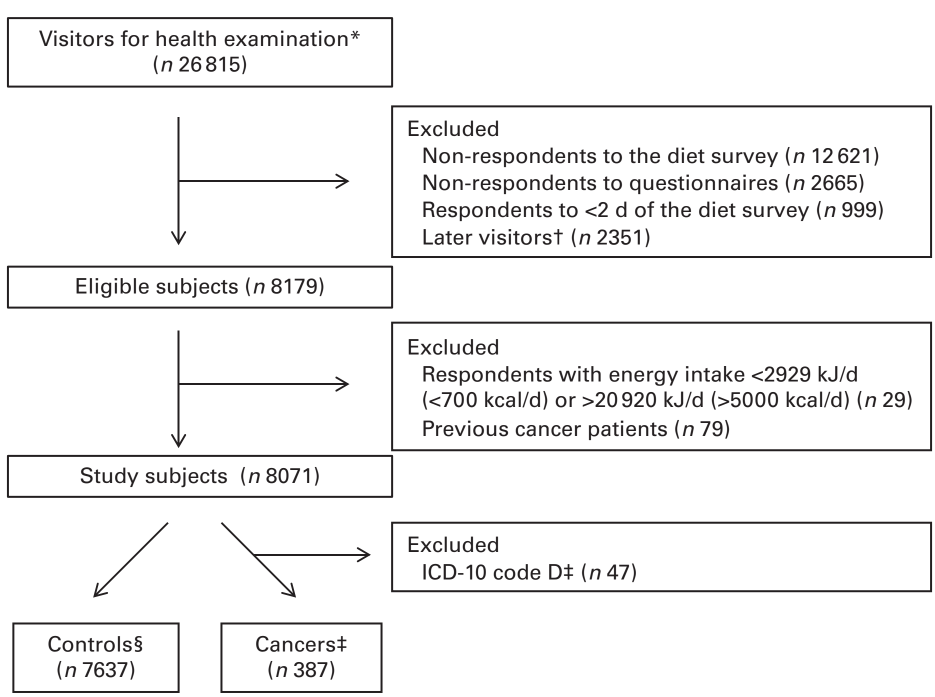

Fig. 1. Inclusion and exclusion criteria for the study subjects. * Visitors for the health examination survey from 1 September 2004 to 31 December 2008. † Excluded the data from the first visit if the participants visited more than twice. ‡ Newly detected cancer according to the WHO International Classification of Diseases (ICD)-10 as of 24 September 2013. § No detected cancer or previous cancer history as of 24 September 2013.

the accuracy of food records, trained registered dietitians confirmed all records written by subjects with face-to-face interviews. The daily intake of energy, nutrients, food and food groups for each subject were calculated using CAN-Pro 3.0 (Korean Nutrition Society).

Dietary risk factors

We investigated four dietary risk factors (high intakes of red meat and Na, low intakes of vegetables and fruits, and obesity) based on *a priori* knowledge of risk factors for overall cancer incidence. Because no dietary guidelines for cancer prevention are available in Korea, the recommendations for the intakes of red meat, fruits and vegetables, and Na provided by the WCRF/AICR (2007) were adopted as reference intakes for cancer-related dietary factors[3]. The WCRF/AICR recommended that the consumption of red meat and Na should be limited to <300 g/week (43 g/d) and <4 g/d, respectively, and intakes of vegetables and fruits should be at least 600 g/d. In the present study, red meat referred to beef, pork, lamb and goat, and processed meats. Processed meats included meats contained in processed foods such as bacon, ham and sausage, and the internal organs (offal, such as the brain, liver, heart, intestines and tongue). Vegetables were considered as the edible parts of plants, which generally includes fungi, and fruits were considered as the seed-containing part of plants. Vegetables and fruits preserved by salting and/or pickling (e.g. kimchi in Korea) were not included. Na intake was estimated from 3 d food records by Can-Pro 3.0 (Korean Nutrition Society).

Obesity was considered as a dietary risk factor because this condition reflects excessive energy intake. Each factor was dichotomised into two categories: no risk (0 points) and risk (1 point). All participants scored 1 point for each of the following dietary risk factors at baseline: ≥43 g red meat/d; <600 g vegetables and fruits/d; ≥4 g Na/d; obesity (BMI ≥25 kg/m^2). We determined the number of dietary risk factors per participant by summing the scores for each of the four dietary risk factors; consequently, the number of dietary risk factors ranged from 0 to 4 points.

Statistical analyses

The characteristics of the study population were described as the number and percentage of subjects in the cancer and control groups, and the χ^2 test and generalised linear regression analysis were used to compare the distributions of subjects and mean differences between the two groups, respectively. The hazard ratio (HR) and 95 % CI were estimated using the Cox proportional hazards regression model. The multivariate model was adjusted for age, sex, energy intake, BMI, physical activity (yes or no), smoking (yes or no), alcohol use (yes or no), income (three categories), education (three categories) and marital status (three categories). In addition, HR in several subgroups were analysed: sex (male, female); age (<50 years, ≥50 years); cancer sites (thyroid, gastric and colon cancers).

All statistical analyses were performed using SAS software (version 9.1.3; SAS Institute, Inc.). Statistical significance was set at $P<0·05$.

Results

During 54 027 person-years of follow-up (median 7·0 years), 387 subjects were diagnosed with cancer. The detailed characteristics of the study subjects are shown in Table 1.In comparison with the controls, cancer subjects were older ($P<0·0001$), had lower levels of income ($P=0·0135$) and education ($P=0·0031$), and were less likely to be married ($P=0·0368$). There were no significant differences in smoking or physical activity between the cancer and control groups. The total food intake of the control group was higher than that of the cancer group ($P=0·0237$). The percentage of participants with more than three dietary risk factors in the cancer group was higher than that of the control group ($P=0·0387$).

The HR of cancer according to dietary risk factors is presented in Table 2.

Obesity (BMI ≥25 kg/m^2) was significantly associated with overall cancer risk (crude HR 1·24) in total subjects and in women (crude HR 1·60), but the associations were disappeared after adjusting for confounding variables such as age, energy intake and other demographic factors.

The risk of cancer in male was significantly increased among individuals who consumed at least 43 g red meat/d (or 300 g/week) compared with those who ate less than 43 g/d (or 300 g/week) (HR 1·41, 95 % CI 1·02, 1·94; $P=0·0382$) after adjusting for confounding variables.

There were no significant differences in cancer incidence for the intakes of vegetables and fruits and Na between the cancer and control groups.

The subjects with more than three dietary risk factors among obesity and high intakes of red meat and Na, and low intakes of fruits and vegetables had increased cancer incidence compared with those with two dietary risk factors or less among the total population (crude HR 1·24, 95 % CI 1·01, 1·51; $P=0·0372$), women (crude HR 1·52, 95 % CI 1·11, 2·09; $P=0·0089$) and those subjects younger than 50 years of age (crude HR 1·44, 95 % CI 1·06, 1·96; $P=0·0216$); however, these significant associations were disappeared after adjusting for confounding variables.

The risk of thyroid, gastric and colorectal cancers, which were most prevalent among Koreans[38], according to the status of having dietary risk factors are shown in Table 3.

The risk of thyroid cancer was higher in the obese subjects (BMI ≥25 kg/m^2) than the normal-weight subjects (HR 1·56, 95 % CI 1·05, 2·31; $P=0·0270$), and the risk of gastric cancer was positively associated with age (HR 2·49, 95 % CI 1·24, 4·99; $P=0·0103$; data not shown) and Na intake (HR 2·34, 95 % CI 1·06, 5·19; $P=0·0365$) after adjusting for confounding variables.

While the risk of colorectal cancer was not significantly associated with the dietary risk factors, the risk of gastrointestinal cancers including gastric and colorectal cancers was positively associated with Na intake (HR 4·28, 95 % CI 2·11, 8·72; $P<0·0001$) and the number of dietary risk factors (HR 1·87, 95 % CI 1·03, 3·37; $P=0·0386$) after adjusting for confounding variables.

Table 1. Characteristics of the study subjects

(Mean values and standard deviations; number of subjects and percentages)

			Controls* (*n* 7637)		Cancer subjects: Total cancers* (*n* 387)		Thyroid cancer (*n* 136)		Gastric cancer (*n* 46)		Colorectal cancer (*n* 53)		Gastric and colorectal cancer (*n* 99)	
	Person-years	Median	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Demographic factors														
Sex, female	24476·2	7·0	3457	45·3	165	42·6	72	52·9	15	32·6	30	37·7	45	45·5
Age (years)														
Mean			48·4		52·5		49·3		54·1		52·1		53·0	
SD			9·2		9·6		8·0		9·1		10·6		9·9	
< 50 years	30287·0	6·9	4343	56·9	163	42·1	78	57·4	15	32·6	23	43·4	38	38·4
≥ 50 years	23739·7	7·1	3294	43·1	224	57·9	58	42·7	31	67·4	30	56·6	61	61·4
BMI (kg/m^2)														
Mean			23·8		24·3		24·3		24·8		24·6		24·7	
SD			2·9		2·9		2·9		2·2		3·8		3·2	
< 25·0 kg/m^2	32463·1	6·9	4598	60·2	212	54·8	72	52·9	20	43·5	34	64·2	54	45
≥ 25·0 kg/m^2	21613·0	7·0	3039	39·8	175	45·2	64	47·1	26	56·5	19	35·8	54·5	45·5
Income														
≤ 4 millions/month	19455·4	7·1	2703	35·4	161	41·6	62	45·6	19	41·3	19	35·8	38	14
400–700 millions/month	20972·5	7·4	2886	37·8	117	30·2	39	28·7	13	28·3	19	35·8	38·4	14·1
≥ 700 millions/month	8705·3	6·1	1363	17·8	68	17·6	24	17·6	6	13·0	8	15·1	32	15
Missing†	4943·0	7·1	685	9·0	41	10·6	11	8·1	8	17·4	7	13·3	32·3	15·2
Education														
≤ Middle school	6895·7	7·1	951	12·4	68	17·6	25	18·4	10	21·7	8	15·1	18	49
High school	18002·0	6·8	2570	33·7	123	31·8	42	30·9	12	26·1	12	22·6	18·2	49·5
≥ College	27738·8	7·0	3918	51·3	178	46·0	64	47·0	21	45·7	28	52·8	24	8
Missing†	1434·5	6·9	198	2·6	18	4·6	5	3·7	3	6·5	5	9·5	24·2	8·1
Marital status														
Unmarried	1432·0	6·9	206	2·7	7	1·8	3	2·2	1	2·2	0	0·0	1	7
Married	48772·1	7·0	6883	90·1	337	87·1	116	85·3	40	87·0	43	81·1	1·0	7·1
Divorced/widowed	2658·2	6·6	380	5·0	27	7·0	12	8·8	1	2·2	6	11·3	83	8
Missing†	1213·8	6·9	168	2·2	16	4·1	5	3·7	3	8·6	4	7·6	83·8	8·1
Behavioural factors														
Smoking														
No	24940·0	6·9	3555	46·5	177	45·7	75	55·2	16	34·8	25	47·2	41	41·4
Current or former	24279·2	6·8	3462	45·3	179	46·3	52	38·2	24	52·2	24	45·3	18	48·5
Missing†	4857·0	7·7	620	8·2	31	8·0	9	6·6	6	13·0	4	7·5	10	10·1
Alcohol use														
No	13664·9	6·9	1944	25·5	103	26·6	40	29·4	10	21·7	16	30·2	26	26·3
Current or former	37318·7	7·0	5262	68·9	264	68·2	86	63·2	35	76·1	35	66·0	70	70·7
Missing†	3092·6	6·9	431	5·6	20	5·2	10	7·4	1	2·2	2	3·8	3	3·0
Regular physical activity														
Yes	24002·4	7·5	3199	41·9	147	38·0	45	33·1	23	50·0	22	41·5	45	45·4
No	26108·1	6·1	3933	51·5	204	52·7	78	57·3	20	43·5	27	50·9	47	47·5
Missing†	3965·6	7·6	505	6·6	36	9·3	13	9·6	3	6·5	4	7·6	7	7·1

https://doi.org/10.1017/S0007114514000683 Published online by Cambridge University Press

Table 1. *Continued*

			Cancer subjects											
			Controls* (*n* 7637)		Total cancers* (*n* 387)		Thyroid cancer (*n* 136)		Gastric cancer (*n* 46)		Colorectal cancer (*n* 53)		Gastric and colorectal cancer (*n* 99)	
	Person-years	Median	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Dietary factors														
Total food intake (g/d)														
Mean			1362·4		1312·5		1365·4		1297·9		1241·3		1267·6	
SD			465·7		415·5		462·5		416·7		378·4		395·6	
Red meat (g/d)														
Mean			73·8		70·5		71·7		64·2		64·0		64·1	
SD			64·0		59·9		65·4		54·9		51·9		53·1	
< 43 g/d	23049·8	7·0	2963	36·6	165	42·6	61	44·9	22	47·8	22	41·5	44	44·4
≥ 43 g/d	30976·8	7·0	4674	63·4	222	57·4	75	55·1	24	52·2	31	58·5	55	55·6
Vegetables and fruits (g/d)														
Mean			411·4		406·4		416·6		415·5		401·6		408·1	
SD			259·5		245·5		261·8		281·9		236·5		257·3	
< 600 g/d	44186·3	6·9	6251	81·8	315	81·4	108	79·4	36	78·3	43	81·1	79	79·8
≥ 600 g/d	9889·9	7·1	1386	18·2	72	18·6	28	20·6	10	21·7	10	18·9	20	20·2
Na (mg/d)														
Mean			4239·8		4264·5		4335·6		4217·9		4013·9		4108·7	
SD			1682·1		1691·3		1798·5		1437·7		1513·7		1474·9	
< 4000 mg/d	26679·9	7·0	3777	49·5	187	48·3	68	50·0	20	43·5	28	52·8	48	48·5
≥ 4000 mg/d	27396·4	7·0	3860	50·5	200	51·7	68	50·0	26	56·5	25	47·2	51	51·5
No. of dietary risk factors‡														
≤ 2	31202·0	7·0	4296	56·3	204	52·7	75	55·1	22	47·8	30	56·6	52	52·5
≥ 3	22824·6	6·9	3341	43·7	183	47·3	61	44·9	24	52·2	23	43·4	47	47·5

* Tests of the association between the control and total cancer groups performed using the χ^2 test (categorical variables) or a generalised linear model (continuous variables) adjusted for sex and age.
† Missing included no response or unwilling to respond.
‡ All participants scored 1 point for each of the following dietary risk factors (high intakes of red meat and Na, low intakes of vegetables and fruits, and obesity) at baseline: ≥43 g red meat/d; <600 g vegetables and fruits/d; ≥4000 mg Na/d; obesity (BMI ≥25 kg/m^2). The number of dietary risk factors ranged from 0 to 4 points.

https://doi.org/10.1017/S0007114514000683 Published online by Cambridge University Press

Table 2. Hazard ratios (HR) for overall cancer according to dietary risk factors
(Hazard ratios and 95 % confidence intervals)

	Total (*n* 8024)				Sex: Male (*n* 4402)				Sex: Female (*n* 3622)				Age: < 50 years (*n* 4506)				Age: ≥ 50 years (*n* 3518)			
	Crude		Multivariate		Crude		Multivariate		Crude		Multivariate		Crude		Multivariate		Crude		Multivariate	
	HR*	95 % CI	HR†	95 % CI	HR*	95 % CI	HR†	95 % CI	HR*	95 % CI	HR†	95 % CI	HR*	95 % CI	HR†	95 % CI	HR*	95 % CI	HR†	95 % CI
Person-years	54 076				29 583				24 493				30 314				23 762			
Median	7·0				6·9				7·0				6·9				7·1			
Range	0-9·1				0·0-9·1				0·0-9·1				0·0–9·1				0·0–9·1			
BMI (kg/m^2)																				
< 25	1·00		1·00		1·00		1·00		1·00		1·00		1·00		1·00		1·00		1·00	
≥ 25	1·24	1·01, 1·51	1·15	0·91, 1·45	1·03	0·79, 1·33	1·09	0·82, 1·46	1·60	1·16, 2·19	1·48	0·98, 2·24	1·30	0·95, 1·77	1·34	0·92, 1·96	1·10	0·85, 1·44	1·08	0·79, 1·46
P	0·0364		0·2554		0·8559		0·5629		0·0039		0·0623		0·0965		0·1314		0·4339		0·6343	
Red meat (g/d)																				
< 43	1·00		1·00		1·00		1·00		1·00		1·00		1·00		1·00		1·00		1·00	
≥ 43	1·06	0·86, 1·30	1·23	0·96, 1·57	1·06	0·80,1·41	1·41	1·02, 1·94	1·02	0·75, 1·38	0·97	0·66, 1·44	1·14	0·81, 1·59	1·26	0·84, 1·88	1·18	0·90, 1·53	1·19	0·87, 1·63
P	0·5902		0·1042		0·6834		0·0382		0·9050		0·8851		0·4541		0·2597		0·2308		0·2835	
Vegetables and fruits (g/d)																				
< 600	1·00		1·00		1·00		1·00		1·00		1·00		1·00		1·00		1·00		1·00	
≥ 600	1·03	0·79, 1·33	1·02	0·75, 1·37	0·94	0·67, 1·34	0·93	0·63, 1·38	1·15	0·79, 1·67	1·14	0·71, 1·85	1·05	0·69, 1·60	1·11	0·69, 1·80	0·92	0·66, 1·27	0·95	0·65, 1·40
P	0·8425		0·9217		0·7404		0·7229		0·4786		0·5864		0·8076		0·6738		0·5947		0·7923	
Na (mg/d)																				
< 4000	1·00		1·00		1·00		1·00		1·00		1·00		1·00		1·00		1·00		1·00	
≥ 4000	1·04	0·86, 1·27	1·18	0·91, 1·52	0·97	0·75, 1·27	1·28	0·93, 1·76	1·09	0·80, 1·49	1·01	0·66, 1·56	1·13	0·83, 1·55	1·36	0·92, 2·02	1·02	0·78, 1·32	1·06	0·76, 1·49
P	0·6760		0·2096		0·8500		0·1347		0·5707		0·9515		0·4236		0·1254		0·9136		0·7262	
No. of dietary risk factors‡																				
≤ 2	1·00		1·00		1·00		1·00		1·00		1·00		1·00		1·00		1·00		1·00	
≥ 3	1·24	1·01, 1·51	1·26	0·99, 1·60	1·05	0·80, 1·36	1·31	0·97, 1·77	1·52	1·11, 2·08	1·23	0·81, 1·88	1·44	1·05, 1·96	1·46	0·99, 2·16	1·19	0·91, 1·55	1·17	0·86, 1·61
P	0·0372		0·0658		0·7482		0·0772		0·0091		0·3336		0·0218		0·0545		0·2035		0·3201	

* Estimated using the Cox proportional hazards regression model.
† Estimated using the Cox proportional hazards regression model, adjusted for age, sex, energy intake, BMI, physical activity, smoking, alcohol use, income, education and marital status.
‡ All participants scored 1 point for each of the following dietary risk factors (high intakes of red meat and Na, low intakes of vegetables and fruits, and obesity) at baseline: ≥ 43 g red meat/d; < 600 g vegetables and fruits/d; ≥ 4000 mg Na/d; obesity (BMI ≥ 25 kg/m^2). The number of dietary risk factors ranged from 0 to 4 points.

https://doi.org/10.1017/S0007114514000683 Published online by Cambridge University Press

Table 3. Hazard ratios (HR) for major cancers according to dietary risk factors
(Hazard ratios and 95 % confidence intervals)

	Thyroid cancer (*n* 136)				Gastric cancer (*n* 46)				Colorectal cancer (*n* 53)				Gastric and colorectal cancers (*n* 99)			
	Crude HR*	95 % CI	Multivariate HR†	95 % CI	Crude HR*	95 % CI	Multivariate HR†	95 % CI	Crude HR*	95 % CI	Multivariate HR†	95 % CI	Crude HR*	95 % CI	Multivariate HR†	95 % CI
Person-years	223				68				53				121			
Median	0·7				0·3				0·1				0·1			
Range	0·0–8·3				0·0–8·4				0·0–6·0				0·0–8·4			
BMI (kg/m^2)																
< 25 kg/m^2	1·00		1·00		1·00		1·00		1·00		1·00		1·00		1·00	
≥ 25 kg/m^2	1·34	0·96, 1·87	1·56	1·05, 2·31	1·96	1·09, 3·51	1·84	0·90, 3·76	0·85	0·48, 1·48	0·64	0·32, 1·26	0·88	0·59, 1·31	0·76	0·43, 1·33
P	0·0898		0·0273		0·0239		0·0941		NS		NS		NS		NS	
Red meats (g/d)																
< 43	1·00		1·00		1·00		1·00		1·00		1·00		1·00		1·00	
≥ 43	0·91	0·65, 1·28	0·91	0·61, 1·36	0·76	0·42, 1·35	1·16	0·56, 2·41	1·05	0·60, 1·82	1·31	0·60, 2·61	1·11	0·74, 1·65	1·48	0·83, 2·64
P	NS		NS		NS		NS		NS		NS		NS		NS	
Vegetables and fruits (g/d)																
< 600	1·00		1·00		1·00		1·00		1·00		1·00		1·00		1·00	
≥ 600	0·86	0·57, 1·30	0·87	0·54, 1·42	0·80	0·40, 1·62	0·83	0·35, 1·98	0·96	0·48, 1·90	0·85	0·38, 1·92	0·91	0·55, 1·51	0·72	0·38, 1·36
P	NS		NS		NS		NS		NS		NS		NS		NS	
Na (mg/d)																
< 4000	1·00		1·00		1·00		1·00		1·00		1·00		1·00		1·00	
≥ 4000	0·98	0·70, 1·37	1·11	0·72, 1·69	1·27	0·71, 2·28	2·34	1·05, 5·19	0·87	0·51, 1·50	1·52	0·75, 3·08	1·57	1·04, 2·35	4·28	2·11, 8·72
P	NS		NS		NS		0·0367		NS		0·2446		0·0303		< 0·0001	
No. of dietary risk factors‡																
≤ 2	1·00		1·00		1·00		1·00		1·00		1·00		1·00		1·00	
≥ 3	1·08	0·77, 1·51	1·16	0·78, 1·75	1·53	0·86, 2·73	2·07	0·99, 4·33	0·99	0·57, 1·70	1·04	0·53, 2·04	1·11	0·74, 1·65	1·87	1·03, 3·37
P	NS		NS		NS		0·0533		NS		NS		NS		0·0386	

* Estimated using the Cox proportional hazards regression model.
† Estimated using the Cox proportional hazards regression model, adjusted for age, sex, energy intake, BMI, physical activity, smoking, alcohol use, income, education and marital status.
‡ All participants scored 1 point for each of the following dietary risk factors (high intakes of red meat and Na, low intakes of vegetables and fruits, and obesity) at baseline: ≥ 43 g red meat/d; < 600 g vegetables and fruits/d; ≥ 4000 mg Na/d; obesity (BMI ≥ 25 kg/m^2). The number of dietary risk factors ranged from 0 to 4 points.

https://doi.org/10.1017/S0007114514000683 Published online by Cambridge University Press

Discussion

This is the first prospective cohort study using the open-ended dietary assessment method to estimate the association between dietary risk factors and cancer incidence among Koreans, and found that dietary risk factors such as red meat and Na intakes were significantly positively associated with cancer risk in a Korean population.

People are living longer than ever before, and the incidence of cancer has been increased with ageing[39–41]. In the present study, overall cancer risk was positively associated with age and significantly higher in individuals older than or equal to 50 years compared with those younger than 50 years of age (HR 1·80, 95 % CI 1·41, 2·31; $P<0·0001$; data not shown).

We also found that obesity (BMI $\geq 25\,kg/m^2$) tended to increase the risk of overall cancer in women, which was positively associated with the risk of thyroid cancer. Many studies have reported that overweight ($25 \leq$ BMI $< 30\,kg/m^2$) and obese (BMI $\geq 30\,kg/m^2$) individuals have an increased risk of various cancers, primarily in Western populations, but not among Asians[7,17,18,20,21]. In contrast, one 14-year prospective cohort study conducted by the National Health Insurance Corporation in Koreans has shown that obesity was significantly associated with an increased risk of cancer[19]. The obesity criteria (BMI $\geq 30\,kg/m^2$) used in the studies for the Western population were different from those for Asians (BMI $\geq 25\,kg/m^2$). Because Asian populations generally have a higher percentage of body fat compared with the Westerners at the same BMI[36], our findings support that overweight ($23 \leq$ BMI $< 25\,kg/m^2$) as well as obesity (BMI $\geq 25\,kg/m^2$) can also contribute to the risk of cancer in Korean populations.

Most previous studies have reported that red meat consumption is an important risk factor for cancer at several sites[7–13]. In the present study, a significant positive association between red meat intake and overall cancer risk was observed only in men. We speculated the reason why the risk of meat intake increased cancer risk only in men, and found that the meat intake level was significantly higher in men than in women. The mean intake of red meat and the percentage of individuals who consumed at least 43 g red meat daily were significantly higher in men (85·3 g and 68·1 %, respectively) than in women (59·5 g and 52·9 %, respectively) ($P<0·0001$, data not shown). In contrast, the effects of red meat type, fresh and processed red meat on the risk of cancer were analysed. We found that fresh red meat was not associated with cancer risk, while processed red meat intake was positively associated with cancer risk in men (HR 1·05, 95 % CI 1·00, 1·92; $P=0·0343$) and in individuals older or equal to 50 years of age (HR 1·07, 95 % CI 1·02, 1·13; $P=0·0068$) (data not shown).

These results suggested that meat intake, especially processed meat intake, of men or people older than or equal to 50 years of age should be cautioned for cancer prevention.

To our knowledge, many previous studies have examined the combined effects of lifestyle-related risk factors, including diet, on cancer risk[3,7,42–48], but not many studies have examined the effects of combined dietary risk factors on cancer risk in Asia, especially in Korea. Notably, we found that the combined effects of dietary risk factors on overall cancer risk were greater than the individual effects. These results provide new evidence that dietary risk factors, including red meat and Na intakes, and obesity, may contribute to increased cancer risk in a population when combined, as in those who are experiencing a dietary transition from a traditional diet composed of mainly rice and vegetables to a Westernised diet.

Dietary risk factors are known to be distinct according to the cancer site. Many previous studies have suggested that the heavy consumption of Na is a risk factor for gastric cancer[3,15,16], red meat consumption is for colorectal cancer[7–10] and obesity is for thyroid cancer[3,49,50]. We also observed that the risk of gastric cancer increased with Na intake and thyroid cancer risk was increased with obesity.

Previous studies have suggested that thyroid cancer was linked to iodine intake[3,51]. We analysed the association between thyroid cancer and seaweeds as the main sources of iodine, because there was no available iodine database for common foods in Korea. Seaweed intake was higher in the thyroid cancer group (4·28 (SD 12·0) g/d) than in the control group (4·19 (SD 13·6) g/d), but there was no statistically significant association between seaweed consumption and the risk of thyroid cancer (data not shown). Further studies are needed to clarify the association between the risk of thyroid cancer and iodine or seaweed intake.

Both gastric cancer and colorectal cancer risks were not associated with the number of dietary risk factors, but the risk of gastrointestinal cancers including both sites was positively associated with the number of dietary risk factors. The reason may be due to the increased number of cancer patients to get sufficient analysis power.

The strength of the present study was its large prospective cohort design, which enabled us to investigate the association between diet and cancer risk in Korea. Second, the present study used 3 d dietary records, which can accurately measure the dietary intake of subjects, and recall bias and reverse causation were minimised by the assessment of diet before cancer diagnosis. Moreover, since all kinds of meat consumed by the subjects were measured, the amount of red meat intake must be accurate to provide statistical power to detect associations.

The present study also had certain limitations. First, the mean follow-up period of the cohort in the present study was 6·7 years, which might be insufficient to identify a large number of incident cancer cases for statistical power. The small number of cancer cases may limit an adequate assessment of the relationship between diet and cancer, result in low statistical power to identify the association and cause potential problems according to the multiple testing. Second, the present study was conducted with self-motivated participants in a hospital setting, and thus might be susceptible to selection bias. The participants in the present study were limited to those individuals who could afford the expenses of the cancer screening programme. Third, the dietary risk factors used in the present study were subjectively selected according to the WCRF/AICR recommendation; because dietary guidelines have not been developed to prevent cancer in Koreans and few studies have been performed to identify dietary risk factors in Koreans, important dietary risk factors were not included in the analysis. Fourth, dietary information might not reflect an individual's usual intake because we used 3 d food records.

In conclusion, we observed a positive association between red meat and Na intakes and cancer risk in the Korean population. The findings can be applied to develop and evaluate a cancer control programme for Koreans, although further studies are needed to clarify dietary risk factors for cancer at specific sites among Koreans.

Supplementary material

To view supplementary material for this article, please visit http://dx.doi.org/10·1017/S0007114514000683

Acknowledgements

The authors are indebted to the dietitians at the National Cancer Center for data collection.

The present study was partially supported by the National Cancer Center of the Republic of Korea (NCC0910220).

The authors' responsibilities were as follows: G.-A. W., J. K. and H. J. designed the research; Y.-A. C., H.-h. K., K.A. R., and M.-K. Y. conducted the research; G.-A. W. analysed the data and wrote the manuscript; K.-W. J. helped to analyse and interpret the data; Y.-A. K. and J.-H. L. helped to draft the manuscript; G.-A. W. and H. J. had primary responsibility for the final content. All authors read and approved the final manuscript.

None of the authors had a conflict of interest.

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