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Development of the anti-cancer food scoring system 2.0: Validation and nutritional analyses of quantitative anti-cancer food scoring model

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BACKGROUND/OBJECTIVE: We have previously designed the anti-cancer food scoring model (ACFS) 1.0, an evidence-based quantitative tool analyzing the anti-cancer or carcinogenic potential of diets. Analysis was performed using simple quantitative indexes divided into 6 categories (S, A, B, C, D, and E). In this study, we applied this scoring model to wider recipes and evaluated its nutritional relevance.
MATERIALS/METHODS: National or known regional databases were searched for recipes from 6 categories: Korean out-dining, Korean home-dining, Western, Chinese, Mediterranean, and vegetarian. These recipes were scored using the ACFS formula and the nutrition profiles were analyzed.
RESULTS: Eighty-eight international recipes were analyzed. All S-graded recipes were from vegetarian or Mediterranean categories. The median code values of each category were B (Korean home-dining), C (Korean out-dining), B (Chinese), A (Mediterranean), S (vegetarian), and D (Western). The following profiles were correlated ($P < 0.05$) with ACFS grades in the univariate trend analysis: total calories, total fat, animal fat, animal protein, total protein, vitamin D, riboflavin, niacin, vitamin B_{12}, pantothenic acid, sodium, animal iron, zinc, selenium, and cholesterol (negative trends), and carbohydrate rate, fiber, water-soluble fiber, vitamin K, vitamin C, and plant calcium (positive trends). Multivariate analysis revealed that animal fat, animal iron, and niacin (negative trends) and animal protein, fiber, and vitamin C (positive trends) were statistically significant. Pantothenic acid and sodium showed non-significant negative trends ($P < 0.1$), and vitamin B_{12} showed a non-significant positive trend.
CONCLUSION: This study provided a nutritional basis and extended the utility of ACFS, which is a bridgehead for future cancer-preventive clinical trials using ACFS.

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INTRODUCTION

Cancer is a non-communicable disease and is the leading cause of death globally [1]. In the United States, it is the second leading cause of death, following cardiovascular diseases. In Korea and Japan, it is the first leading cause of death [2-4]. Causes of cancer vary widely and many remain unknown; however, the most significant known causes are smoking and diet [5]. Doll and Peto previously estimated that each of these 2 causes accounted for about one-third of cancer causes [6]. In a recent large prospective study, cancer-specific mortality was found to be reduced to 61% in a population that adhered to the cancer prevention recommendations by the World Cancer Research Fund (WCRF) and the American Institute for Cancer Research (AICR) [7], aligning with the estimates of the research conducted by Doll and Peto.

The method of controlling the risk factor for smoking is simply cessation. However, identifying the foods beneficial for cancer prevention and those that are carcinogenic is more complex. A variety of studies on the relationship between cancer and food, from laboratory to large-scale population studies, have been published [8-11]. However, the results of these studies were diverse, and the studies differed from each other in terms of design; moreover, large differences were found according to region and culture. Furthermore, commercial information with inadequate scientific evidence has been widespread and has led to confusion in the general population.

Food is consumed daily by everyone in every socioeconomic

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class. Obtaining evidence-based information about foods that can prevent cancer among people without nutritional and medical expertise is difficult. Therefore, establishing an intuitive anti-cancer or carcinogenic food index is very useful in promoting cancer-related health.

Based on these needs, we developed the anti-cancer food scoring model (ACFS) 1.0 [12]. The ACFS 1.0 model assigned points to 22 food elements using a systematic method based on literature evaluation. The points were added up based on composition ratios, and unhealthy cooking methods (high salt or oil) were taken into account, to arrive at any of the 6 anti-cancer grades. This model has the advantage of easy-to-understand points and grades, integrating a vast amount of information from the literature.

This study aimed to apply the previously constructed ACFS algorithm to various international recipes, including Mediterranean, vegetarian, Chinese, Western, and Korean diets, and to verify the nutritional validity of the model using a computer-aided nutrition analysis based on the obtained information.

MATERIALS AND METHODS

Calculation model of ACFS

Here, we introduce the calculation model of ACFS briefly, as described in more detail in our previous article [12]. First, we set the 22 ACFS food element codes that are diverse enough to evaluate the majority of Western and Asian recipes. They include whole grain (WG), red meat (RM), green leafy salad (GLS), fish (FISH), garlic (Ga), soy food (SF), cruciferous vegetable (CV), allium vegetable (AV), cheese (Ch), seaweed (SW), fruit (FR), non-starchy vegetable (NSV), white meat (WM), carotene-rich vegetable (CRV), processed meat (PM), selenium-rich food (SRF), milk (Mi), egg (Egg), refined grain (RG), legume (Le), chili (Chili), and potato (Pot).

For each code, studies on 5 major cancers (i.e., breast, colorectal, stomach, lung, and liver) with high global mortality and affected by diets were analyzed. Literature evaluation was based on the 2nd expert report of WCRF/AICR [13]. In the 2nd expert report of WCRF/AICR, the level of evidence was classified into 4 stages (convincing, probable, limited-suggestive, and limited-no conclusion). Level of evidence was determined by the number of cohort or case-control studies, quality of the studies, heterogeneity among the studies, and biological plausibility. In ACFS, code grade A is allotted for convincing or probable, code grade B for limited-suggestive, and code grade C for limited-no conclusion. Then, 10, 5, and 2 points were assigned to code grades A, B and C, respectively. Assigned code points according to each of the 5 cancers, defined as "cancer specific grades", were summed to yield "ACFS code grades" from A to E.

The meals analyzed were divided into constituent components and matched with the ACFS codes. The "ingredient score" was calculated by multiplying the ratio (using food exchange unit, FEU) of each component in the meal with the code grade point (A, B, C, D, and E correspond to 5,4,3,2,1 points respectively). FEU was used instead of the weight of the ingredient because of its similarity to serving size, which was the more commonly used measurement than weight in reference studies [12,50]. FEUs for Korean and Chinese recipes were based on the Korean Diabetes Food Exchange Table. FEUs for Western, vegetarian, and Mediterranean recipes were calculated from the American Dietetic Association Food Exchange Table. The grade level, out of 5 grade levels, was determined from the ingredient scores and the meal was downgraded 1 level if it was cooked using an unhealthy method (> 2 g of salt or > 20 g of oil used in cooking). The final grade was named as the ACFS grade and was interpreted as follows:

Grade S, ideal for cancer prevention
Grade A, good for cancer prevention
Grade B, might have anticancer potential
Grade C, difficult to be regarded as preventive or carcinogenic
Grade D, might be against cancer prevention
Grade E, probably against cancer prevention.

In Table 1, we have presented the process of calculating the ACFS grade of six sample meals, belonging to six dietary patterns. The calculation algorithm is schematically described in Fig. 1.

Selection of recipes and nutritional analyses

For Chinese recipes, we searched for 'Representative Chinese cuisine' in the People's Network (kr.people.com.cn) and obtained the ingredient information from the websites (https://www.allrecipes.com/, http://cookingsimplechinesefoodathome.com/, http://www.people.com.cn/, all accessed between August 10 and 17, 2018) for the top 10 meals. For 20 Mediterranean and 10 vegetarian meals, commonly considered as healthy diets, the recipes were obtained from "The New Mayo Clinic Cookbook" [14]. For 18 Western meals, we selected the commonly consumed routine daily life meals and obtained the recipes from the following cooking portals, referring to author discussions (https://www.mrbreakfast.com/, https://www.tasteofhome.com/, https://www.seriouseats.com/, all accessed between August 10 and 17, 2018). Fifteen Korean home-dining and 15 Korean out-dining meals were chosen from the frequently consumed meals in the 7th Korea National Health and Nutrition Examination Survey (KNHANES Ⅶ-1), 2016, 24-hour dietary recall data. [15]. For the recipes of the Korean meals, we referred to "The guidelines of using the Korean Diabetes Food Exchange Table" [16], CAN-Pro 5.0 (Computer Aided Nutritional Analysis Program; The Korean Nutrition Society, Seoul, Korea), and the recipe list book published by the Institute of Traditional Korean Food [17].

The nutritional value of the meals was analyzed using CAN-Pro 5.0. Food elements that were too exotic or regional to be analyzed using CAN-Pro were substituted with the most similar elements in the CAN-Pro database (e.g., raspberries were substituted by cranberries, cannellini beans by horse beans, and fennel or finocchio by onion). Carbohydrate, lipid, and protein rates denote the contributing proportion in total calories but not the proportion of component weight.

Ethical approval and informed consent

Ethical approval and consent to participate are not applicable as this study did not involve humans or other living organisms. All investigations conformed to the principles outlined in the Declaration of Helsinki.

ACFS calculation algorithm

1. Anti-cancer food scoring system code grade

① ACFS food codes: 22 food elements
(whole grain, red meat, green leafy salad, fish, garlic, soy food, cruciferous vegetable, allium vegetable, cheese, seaweed, fruit, non-starchy vegetable, white meat, carotene-rich vegetable, processed meat, selenium-rich food, milk, egg, refined grain, legume, chilli, potato)

② Cancer specific grade (CSG) : Each food code is assigned a CSG according to anticancer- or carcinogenic potentials of five cancers (breast, colorectal, stomach, lung, liver).

③ ACFS code grade : The ACFS code grade is determined by adding the points of the cancer specific grade.

[CANCER SPECIFIC GRADE(CSG)]

A (Point 10)	*Convincing* • ≥2 cohort studies or ≥5 case control studies (good qualities) • > 1 study type • Strong biological plausibility (dose-response) • (-) Substantial unexplained heterogeneity *Probable* • ≥2 cohort studies or ≥5 case control studies (good qualities) • Biological plausibility (dose-response) • (-) Substantial unexplained heterogeneity
B (Point 5)	*Limited - suggestive* • ≥2 cohort studies or ≥5 case control studies (good qualities) • General consistency and biological plausibility
C (Point 2)	*Limited - no conclusion* Possibility of relevance but conclusion cannot be made due to limitation of evidence

*Method of evaluating reference was adopted from WCRF/AICR 2nd expert report.

[Anti-cancer food scoring system code table]

No	① ACFS food code	② Cancer specific grade(CSG)					Summed code point	③ Code grade
		Breast	Colo-rectum	Stomach	Lung	Liver		
1	WG(whole grain)	C(2)	A(10)	B(5)			17(=2+10+5)	B
2	RM(red meat)		A(-10)		B(-5)	C(-2)	-17(=-10-5-2)	E
3	GLS(green leafy salad)	C	B	A	B	C	24	A
4	FISH(fish)	C	B		C	B	14	B
5	Ga(garlic)	C	A	A	B		27	A
6	SF(soy food)	B	C	B*			12	B
7	CV(cruciferous vegetable)	C	B	A	B	C	24	A
8	AV(alium vegetable)	C	A	A	B	C	29	A
9	Ch(cheese)		B				5	D
10	SW(seaweed)	C	C				4	C
11	Fr(fruit)	C	B	A	A	B	32	A
12	NSV(non-starchy vegetable)	C	B	A	B	C	24	A
13	WM(white meat)					B	5	C
14	CRV(carotene-rich vegetable)			C	A		12	B
15	PM(processed meat)		A	B	B		-20	E

[Code grade point]

Code grade	Summed code point	Code point
A	> 21	5
B	11~20	4
C	0~10	3
D	-10~-1	2
E	-20~-11	1

2. Ingredient score calculation

① Divide the meal into constituent ingredients.
② Match each ingredient into the relevant ACFS code.
③ Calculate the food exchange unit with weight of each ingredient.
④ Calculate the food exchange unit ratio.
(FEU of each ingredient / Sum of FEUs in the meal X 100)
⑤ Multiply FEU ratios by the code grade points of each ingredient.
⑥ Add all ⑤ value.

3. Cooking modification

• HS (high salt) : > 2g
• HF (high fat) : > 20g
→ Grade is one level lowered

[Examples of ingredient score calculation]

Meal	① Ingredient	Weight (g)	② ACFS code	Code grade	Code grade point	③ FEU (Food Exchange Unit)	④ FEU ratio (%)	⑤ FEU ratio X code grade point	⑥ Ingredient score	Cooking modification	ACFS grade
Chinese style fried rice	White rice	250	RG	D	2	3.5	53.8	107.6			
	Pork	20	RM	E	1	0.5	7.7	7.7			
	Egg	60	Egg	D	2	1	15.4	30.8			
	Carrot	30	NSV	A	5	0.43	6.6	33			
	Onion	40	AV	A	5	0.57	8.8	44			
	Pimento	20	NSV	A	5	0.29	4.5	22.5	Ingredient score : B		
	Scallion	15	AV	A	5	0.21	3.2	16		Cooking modification (High fat)	
					Total FEU : 6.5			Sum	261.6	HF	C

4. ACFS grade

ACFS grade	Ingredient score
S	> 400
A	301-400
B	251-300
C	201-250
D	≤200
E	D is lowered by cooking modification

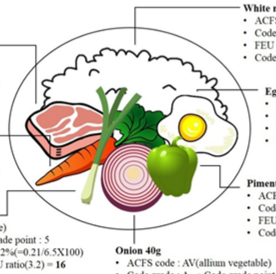
[Examples of ingredient score calculation – Chinese style fried rice]

• Total food exchange unit : 6.5

Pork 20g
• ACFS code : RM(red meat)
• Code grade : E → Code grade point : 1
• FEU 0.5 → FEU ratio : 7.7%(=0.5/6.5X100)
• Code grade point(1) X FEU ratio(7.7) = **7.7**

Carrot 30g
• NSV(non-starchy vegetable)
• Code grade : A → Code grade point : 5
• FEU 0.43 → FEU ratio : 6.6%(=0.43/6.5X100)
• Code grade point(5) X FEU ratio(6.6) = **33**

Scallion 15g
• NSV(non-starchy vegetable)
• Code grade : A → Code grade point : 5
• FEU 0.21 → FEU ratio : 3.2%(=0.21/6.5X100)
• Code grade point(5) X FEU ratio(3.2) = **16**



White rice 250g
• ACFS code : RG(refined grain)
• Code grade : D → Code grade point : 2
• FEU 3.5 → FEU ratio : 53.8%(=3.5/6.5X100)
• Code grade point(2)X FEU ratio(53.8) = **107.6**

Egg 60g
• ACFS code : Egg(egg)
• Code grade : D → Code grade point : 2
• FEU 1 → FEU ratio : 15.4%(=1/6.5X100)
• Code grade point(2) X FEU ratio(15.4) = **30.8**

Pimento 20g
• ACFS code : NSV(non-starchy vegetable)
• Code grade : A → Code grade point : 5
• FEU 0.29 → FEU ratio : 4.5%(=0.29/6.5X100)
• Code grade point(5) X FEU ratio(4.5) = **22.5**

Onion 40g
• ACFS code : AV(allium vegetable)
• Code grade : A → Code grade point : 5
• FEU 0.57 → FEU ratio : 8.8%(=0.57/6.5X100)
• Code grade point(5) X FEU ratio(8.8) = **44**

5. ACFS grade interpretation

S	**Ideal for cancer prevention** in terms of composition and cooking method.
A	**Good for cancer prevention** in terms of composition and cooking method.
B	**Might have cancer prevention** potential and some modification can be helpful.
C	Difficult to be regarded to have **anticancer or carcinogenic** potential. Modification is recommended.
D	**Might be against cancer prevention.** Modification is highly recommended.
E	**Probably against cancer prevention.**

Fig. 1. Calculation algorithm of anti-cancer food scoring system (ACFS)

Table 1. Examples of ACFS grade calculation.

Dietary pattern	Meals	Components	Weight (g)	ACFS code	FEU	FEU ratio (%)	FEU ratio × code grade point	Ingredient score	Cooking modification	ACFS grade
Korean home-dining	Rice	Rice (raw)	90.0	RG	3.00	34.3	69			
	Seaweed soup	Dried seaweed	5.0	SW	0.27	3.1	9			
		Beef	25.0	RM	0.63	7.1	7			
		Garlic	0.7	Ga	0.10	1.1	6			
	Stir fried anchovy	Anchovy	8.8	FISH	0.58	6.7	27			
		Green pepper	1.3	NSV	0.15	0.2	1			
		Red pepper	1.3	NSV		0.2	1			
		Scallion	0.6	AV		0.2	1			
		Garlic	0.7	Ga		1.1	6			
		Sesame	0.5	Le	0.06	0.7	1			
	Braised tofu	Tofu	75.0	SF	0.94	10.7	43			
		Scallion	3.1	AV	0.18	0.9	4			
		Garlic	0.7	Ga		1.1	6			
		Sesame	0.3	Le	0.03	0.4	1			
	Seasoned eggplant	Eggplant	75.0	NSV	1.20	12.2	61			
		Scallion	1.1	AV		0.3	2			
		Garlic	0.7	Ga		1.1	6			
		Sesame	0.5	Le	0.06	0.7	1			
	Young radish kimchi	Flour	0.6	RG	0.02	0.2	0			
		Young radish	83.3	NSV	1.53	13.6	68			
		Scallion	2.1	AV		0.6	3			
		Green pepper	1.3	NSV		0.2	1			
		Red pepper	5.0	NSV		0.8	4			
		Garlic	1.3	Ga		2.2	11			
		Ginger	0.3	NSV		0.1	1	339	HS	B
Korean out-dining	Gimbap	Egg	15.0	Egg	0.27	4.4	9			
		Rice (raw)	80.0	RG	2.67	42.9	86			
		Ham	15.0	PM	0.38	6.0	6			
		Spinach	15.0	CRV	0.42	3.5	14			
		Carrot	15.0	CRV		3.5	14			
		Pickled radish	15.0	NSV	0.46	3.5	17			
		Burdock	10.0	NSV		4.0	20			
		Laver	2.0	SW	1.00	16.1	48			
	Pickled radish	Pickled radish	70.0	NSV	1.00	16.1	81	295	HS	C
Chinese	Di San Xian	Potato	70.0	Potato	0.50	14.0	28			
		Eggplant	105.0	NSV	3.07	42.6	213			
		Bell pepper	70.0	NSV		28.4	142			
		Garlic	3.5	Ga		14.2	71			
		Cheongyang pepper	1.3	NSV		0.5	3	457	HS, HF	B

Table 1. continued

Dietary pattern	Meals	Components	Weight (g)	ACFS code	FEU	FEU ratio (%)	FEU ratio × code grade point	Ingredient score	Cooking modification	ACFS grade
Mediterranean	Cod with vegetables & couscous	Cod	141.7	FISH	5.00	42.2	169			
		Cherry tomatoes	113.4	CRV	1.50	4.2	17			
		Zucchini	87.5	CRV		8.4	34			
		Cooked whole-wheat couscous	186.0	WG	3.54	25.3	101			
		Whole-wheat pita round toast	11.2	WG		4.6	18			
	Apple	Apple	203.4	Fr	1.80	15.2	76	415		S
Vegetarian	Asparagus with hazelnut gremolata	Asparagus	113.4	NSV	0.68	25.3	126			
		Garlic	1.7	Ga	0.26	90	45			
		Fresh flat-leaf parsley	1.0	GLS		0.6	3			
		Hazelnuts	1.6	Le	0.20	7.4	15			
		Lemon zest	3.0	Fr	0.13	3.9	19			
		Fresh lemon juice	2.5	Fr		0.9	5			
	Mango salsa pizza	Green bell peppers	21.9	NSV	0.51	9.3	46			
		Onion	11.4	AV		4.8	24			
		Fresh cilantro	9.8	GLS		4.8	24			
		Whole-grain pizza crust	14.2	WG	0.50	18.5	74			
		Mango	39.0	Fr	0.42	9.3	46			
		Pineapple	40.1	Fr		6.2	31	459		S
Western	Juicy Broiled Burger	Beef	198.4	RM	7.00	58.7	59			
		Cheddar cheese	7.1	Ch	0.25	2.1	4			
		Hamburger buns	56.7	RG	2.00	16.8	34			
	French Fries	Potato	226.8	Potato	2.67	22.4	45	141		D

ACFS, anti-cancer food scoring system; FEU, food exchange unit; RG, refined grain; SW, seaweed; RM, red meat; Ga, garlic; FISH, fish; NSV, non-starchy vegetable; AV, allium vegetable; LE, legume; SF, soy food; EGG, egg; PM, processed meat; CRV, carotene-rich vegetable; Potato, potato; WG, whole grain; Fr, fruit; GLS, green leafy salad; Ch, cheese; HS, high-salt cooking; HF, high-fat cooking. †If 〉 20 g of oil or 〉 2 g of sodium was used for cooking, it was regarded as harmful cooking and the grade was lowered one level.

ACFS grade S, ideal for cancer prevention; A, good for cancer prevention; B, might have anticancer potential; C, difficult to be regarded as preventive or carcinogenic; D, might be against cancer prevention; E, probably against cancer prevention.

Table 2. Nutrition profiles and ACFS scores of 88 international recipes.

code*	Menu	Ingredient score	Cooking modification	ACFS grade	Energy (kcal)	CHO (%)	Animal protein (g)	Fiber (g)	Vitamin C (mg)	Niacin (mg)	Pantothenic acid (mg)	Animal iron (mg)
KH01	Multi-grain Rice, bean paste stew, fried egg, seasoned laver, seasoned spinach, kimchi	366	HS	B	656	55	6	14	91	4.7	1.9	1.1
KH02	Rice, seaweed soup, stir fried anchovy, braised tofu, seasoned eggplant, young radish kimchi	339	HS	B	609	58	9	14	33	3.7	1.5	1.0
KH03	Brown rice90, pork belly80, lettuce, garlic, sesame leaf, green pepper, ssamjang, kimchi	335	HS	B	818	44	18	7	36	4.3	1.3	0.2
KH04	Black rice, kimchi stew, grilled mackerel, seasoned bracken, seasoned bean sprouts, young radish kimchi	297	HS	C	899	40	27	16	42	13.4	2.0	1.9
KH05	Barley rice, bean sprout soup, grilled croaker, bulgogi, seasoned cucumber	310	HS	B	1,015	44	28	10	24	3.5	1.9	0.7
KH06	Samgyetang, diced radish kimchi	323	HS	B	1,643	13	146	4	19	12.8	0.6	7.0
KH07	Bibimbap, beef stew, kimchi	374	HS	B	1,041	53	24	14	49	8.1	2.6	3.0
KH08	Noodles in cold soybean soup, kimchi	407	HS	A	454	73	1	12	22	3.0	0.2	0.2
KH09	Rice, gomtang, diced radish kimchi	192	HS	E	562	60	19	3	17	3.1	1.5	3.0
KH10	Rice, ramen, kimchi	291	HS, HF	D	715	58	6	7	19	2.9	1.2	1.1
KH11	Milk, corn flakes	233		C	350	70	6	1	32	9.1	0.8	0.2
KH12	Rice, seaweed soup, braised Short Ribs, japchae, seasoned spinach, seasoned bracken, kimchi	284	HS, HF	D	1,128	45	30	18	65	9.5	2.5	2.7
KH13	Rice, curry, kimchi	303	HS	B	708	66	8	9	53	4.7	2.1	0.5
KH14	Rice, yukgaejang, diced radish kimchi	319	HS	B	619	59	14	9	38	4.1	1.8	2.2
KH15	Abalone rice porridge, diced radish kimchi	258	HS	C	486	67	6	5	15	2.5	2.5	1.0
KO01	Rice30, pork belly150, lettuce, garlic, sesame leaf, green pepper, ssamjang, kimchi	286	HS	C	1,049	26	33	6	36	3.6	2.1	0.2
KO02	Stir-fried rice cake	323		A	323	86	2	6	9	0.9	0.2	0.1
KO03	Noodles with black soybean sauce, sweet and sour pork, pickled radish	275	HS, HF	D	1,364	48	17	10	34	6.6	1.1	0.9
KO04	Sushi, miso soup, crystallized ginger	331	HS	B	498	70	21	3	1	8.9	1.6	1.0
KO05	Shabu-shabu, Noodle soup	350		A	274	29	14	6	41	5.2	0.1	1.3
KO06	Rice, Korean sausage soup, diced radish kimchi	298	HS	C	506	75	7	7	19	3.1	2.5	5.8
KO07	Roll of bread, cream soup, tenderloin steak, French fries, Green salad, oriental Dressing	200	HS	E	470	46	11	4	35	5.3	1.6	0.7
KO08	Ham egg sandwich, orange juice	314		A	639	48	12	5	100	5.3	1.3	1.3
KO09	Banquet noodles, kimchi	301	HS	B	480	75	8	4	24	3.2	0.6	1.3
KO10	Rice, budae-jjigae, ramen noodle, Corn salad	270	HS	C	722	46	15	10	20	6.3	1.3	1.4
KO11	Triangular Kimbap, instant cup ramen	219	HS	D	378	60	1	2	1	1.6	0.1	0.2
KO12	Chinese fried rice, champon stew, pickled radish	319	HS, HF	C	775	42	15	8	37	3.9	2.4	1.7
KO13	Gimbap, clear broth, pickled radish	295	HS	C	457	64	4	5	24	2.2	1.4	0.5
KO14	Fried Chicken, pickled radish (white)	287	HS, HF	D	1,174	14	63	6	11	9.6	4.0	3.6
KO15	Raw fish bibimbap with tuna, miso soup, crystallized ginger	368	HS	B	487	69	14	7	17	8.6	1.7	1.0
C01	Wonton	132		D	198	48	9	0	1	2.5	0.5	0.9
C02	Kung-bao chicken	354	HS, HF	C	472	20	25	6	11	4.5	0.1	1.2
C03	Braised eggplant	487	HS	A	146	31	0	4	20	0.9	0.4	0.0
C04	Stir-fried Pork Strips in Fish Sauce	269		B	365	21	14	2	5	4.5	1.0	1.6

Table 2. continued

code*	Menu	Ingredient score	Cooking modification	ACFS grade	Energy (kcal)	CHO (%)	Animal protein (g)	Fiber (g)	Vitamin C (mg)	Niacin (mg)	Pantothenic acid (mg)	Animal iron (mg)
C05	Mapa tofu	363		A	264	7	4	6	3	1.8	0.3	0.5
C06	Cihongsu chao zidan	339	HF	B	482	14	13	10	33	2.0	1.8	1.9
C07	Fried pork belly in soy sauce	208	HS	D	582	16	24	6	6	4.1	0.5	1.5
C08	Di San Xian	457	HS, HF	B	320	25	0	6	143	1.7	0.8	0.0
C09	Scrambled eggs with chives	400	HF	B	290	10	7	9	7	1.7	1.0	1.0
C10	Deep-fried shrimp in hot pepper sauce	439	HF, HS	B	350	12	17	6	17	3.0	0.4	2.2
M01	Greek yogurt, strawberries, oats	389		A	357	66	8	14	123	2.3	0.2	0.9
M02	Barley and roasted tomato risotto, Artichokes alla Romana, Almond and apricot biscotti	410		S	323	47	9	8	50	2.2	0.5	0.3
M03	Grouper with tomato-olive sauce, Bean salad with balsamic vinaigrette, Baked apples with cherries and almonds	268	HF	C	1,233	25	25	37	38	10.3	0.3	2.3
M04	Mediterranean-style grilled salmon, Beet walnut salad, Berries marinated in balsamic vinegar	361		A	506	47	30	9	75	11.8	1.6	1.6
M05	Pasta with spinach, garbanzos and raisins, Braised kale with cherry tomatoes, Poached pears	424		S	754	63	2	20	139	5.2	0.3	0.0
M06	Tuscan white bean stew, Fresh tomato crostini	399		A	180	56	0	7	17	2.1	0.6	0.0
M07	Vegetable and garlic calzone, roasted red pepper with feta salad, hard-boiled egg seasoned with a pinch each of salt and pepper	305		A	466	39	15	5	49	3.4	1.3	1.1
M08	Green Salad with Spiced Chickpea Nuts, walnut, dried apricots	374		A	396	30	4	14	48	2.6	0.6	0.1
M09	Tomato & Artichoke Gnocchi, mixed greens	348		A	644	75	0	17	55	6.1	0.3	0.0
M10	Egg & Toast Breakfast, Spiced Chickpea Nuts	271		B	539	41	10	15	127	3.8	1.7	1.0
M11	Cod with Vegetables & Couscous, medium apple	415		S	1,046	66	32	8	148	10.0	0.5	1.3
M12	Green Salad with Pita Bread & Hummus, nonfat plain Greek yogurt topped with strawberries	443		S	430	49	6	12	48	3.9	0.4	0.7
M13	Italian Egg Drop Soup, arugula, whole-wheat bread, toasted and drizzled	372		A	501	35	21	9	30	3.7	0.8	1.3
M14	Roast Pork, Asparagus & Cherry Tomato Bowl, sliced strawberries	229		C	447	45	16	5	123	7.0	1.3	1.8
M15	Mediterranean Tuna Spinach Salad, whole-wheat bread, toasted and drizzled with olive oil, medium fresh fig	383		A	764	35	35	18	215	21.3	1.5	5.2
M16	Chicken Saltimbocca, whole-wheat couscous, steamed broccoli florets	337		A	540	35	46	8	172	9.5	1.1	2.1
M17	Grilled Polenta & Vegetables with Lemon-Caper Vinaigrette, medium plum	395	HF	B	561	39	0	18	35	3.1	0.6	0.0
M18	Cauliflower, Pancetta & Olive Spaghetti, hard-boiled egg seasoned with a pinch each of salt and pepper	362		A	432	54	9	8	100	3.4	1.5	1.0
M19	Garlic, Sausage & Kale Naan Pizzas, medium carrots	361		A	456	31	26	11	149	7.0	1.3	1.5
M20	Sugar Snap Pea Salad, Oatmeal with Fruit & Nuts, clementine	338		A	732	44	8	22	92	4.2	1.2	0.1
V01	Fresh puttanesca with brown rice	403		S	293	74	0	9	33	2.7	0.3	0.0
V02	Asparagus with hazelnut gremolata, Mango salsa pizza	459		S	400	78	3	4	58	2.8	0.5	0.4
V03	Polenta with roasted Mediterranean vegetables, Braised kale with cherry tomatoes	413		S	302	59	0	14	155	4.8	1.2	0.0
V04	Rice noodles with spring vegetables, Cauliflower mashed potatoes	394		A	279	55	0	6	130	2.9	0.7	0.0
V05	Soft tacos with southwestern vegetables	433		S	373	67	0	13	27	2.9	0.8	0.0
V06	Yellow lentils with spinach and ginger, Eggplant with toasted spices	446		S	318	40	0	12	55	3.6	0.5	0.0

Table 2. continued

code*	Menu	Ingredient score	Cooking modification	ACFS grade	Energy (kcal)	CHO (%)	Animal protein (g)	Fiber (g)	Vitamin C (mg)	Niacin (mg)	Pantothenic acid (mg)	Animal iron (mg)
V07	Tomato basil bruschetta, Apple-fennel slaw	436		S	248	70	0	7	30	2.7	0.5	0.0
V08	Asian vegetable salad, Baked apples with cherries and almonds	428		S	406	47	0	13	79	2.9	0.5	0.0
V09	Gazpacho with chickpeas, Peach crumble	431		S	262	62	0	6	14	2.1	0.4	0.0
V10	Vegetarian chili, Orange dream	451		S	258	46	0	9	84	1.8	0.6	0.0
W01	Amish-Style French Toast	207		C	429	45	8	4	1	3.5	1.0	1.0
W02	Simple Bacon Omelet, orange juice, toast	288		B	549	29	23	3	78	5.2	1.6	2.3
W03	Basic Buttermilk Pancakes, blueberry	272		B	464	54	3	4	10	1.7	0.7	0.5
W04	American Flag Fruit Toast	321		A	319	58	2	4	5	2.3	0.3	0.1
W05	Easy Eggs Benedict	184		D	403	30	21	3	2	2.0	1.8	2.6
W06	Juicy Broiled Burger, Thin and Crispy French Fries	141		D	833	30	36	4	11	11.7	1.2	3.2
W07	Grilled Hot Dogs with Sauerkraut	153		D	811	22	28	5	26	7.9	1.2	2.7
W08	Biscuit, Fried Chicken, Honey Butter assembly	250	HF	D	999	26	37	1	0	6.7	2.5	1.9
W09	Chicago-style pizza	194		D	1,347	69	13	13	13	9.9	2.1	1.1
W10	Chocolate Chip Muffins	211		C	137	8	2	1	0	0.2	0.3	0.2
W11	Chicken Cordon Bleu Skillet	233		C	561	44	37	0	13	7.5	0.3	1.6
W12	Meat Loaf & Mashed Red Potatoes	193		D	441	37	20	3	27	7.4	1.5	2.0
W13	Spaghetti & Meatballs	179	HS	E	446	79	3	4	10	4.8	0.4	0.3
W14	Blue Cheese-Crusted Sirloin Steaks, Broccoli with Red Pepper	235		C	728	11	33	5	146	9.9	0.9	2.8
W15	Bean & Beef Slow-Cooked Chili	287		B	1,031	36	13	75	25	9.0	1.2	1.2
W16	Beef & Rice Stuffed Cabbage Rolls	194		D	264	25	15	5	6	4.4	0.2	1.4
W17	Chili-Rubbed Ribs, Cobb Salad	185		D	925	13	77	5	76	11.0	3.3	5.2
W18	Skillet Chicken Fajitas	190		D	621	34	44	4	63	16.4	1.4	1.7

*KH01-15, Korean home-dining; KO01-15, Korean out-dining; C01-10, Chinese; M01-20, Mediterranean; V01-10, vegetarian; W01-18, Western.
ACFS, anti-cancer food scoring system; HF, high fat; HS, high salt.
ACFS grade S, ideal for cancer prevention; A, good for cancer prevention; B, might have anticancer potential; C, difficult to be regarded as preventive or carcinogenic; D, might be against cancer prevention; E, probably against cancer prevention.

Table 3. Univariate analysis among nutrition profiles and ACFS grade groups.

	ACFS E, D (n = 21)	ACFS C, B (n = 35)	ACFS A, S (n = 34)	*P*-value
	Median value (range)			
Total calorie (kcal)	**621.0 (198.0-1,364.0)**	**544.0 (137.0-1,643.0)**	**396.0 (146.0-1,046.0)**	**< 0.001**
*Carbohydrate rate (%)	**37.0 (13.0-76.0)**	**43.0 (8.0-74.0)**	**51.0 (6.0-84.0)**	**0.012**
*Lipid rate (%)	39.0 (6.0-63.0)	39.5 (6.0-85.0)	32.0 (3.0-72.0)	0.066
*Protein rate (%)	19.0 (10.0-35.0)	16.0 (6.0-37.0)	18.0 (5.0-46.0)	0.762
Carbohydrate (g)	55.0 (16.0-227.0)	69.5 (3.0-135.0)	49.0 (4.0-173.0)	0.316
Total fat (g)	**25.0 (3.0-77.0)**	**25.0 (3.0-86.0)**	**13.0 (1.0-35.0)**	**< 0.001**
Plant fat (g)	8.0 (0-42.0)	11.5 (0-48.0)	9.0 (1-25.0)	0.563
Animal fat (g)	**18.0 (0-53.0)**	**9.0 (0-84.0)**	**1.0 (0-13.0)**	**< 0.001**
Protein (g)	**28.0 (10.0-81.0)**	**24.5 (3.0-151.0)**	**17.0 (2.0-61.0)**	**0.004**
Protein, plant (g)	7.0 (3.0-30.0)	8.0 (1.0-64.0)	12.0 (2.0-31.0)	0.059
Animal protein (g)	**20.0 (1.0-77.0)**	**14.0 (0-146.0)**	**3.0 (0-46.0)**	**< 0.001**
Fiber (g)	**4.0 (0-18.0)**	**6.5 (0-75.0)**	**9.0 (4.0-22.0)**	**< 0.001**
Fiber, water soluble (g)	**0.40 (0-4.30)**	**0.85 (0-10.30)**	**1.30 (0.2-3.10)**	**0.001**
Fiber, non-soluble (g)	2.40 (0-11.80)	3.90 (0-61.30)	4.30 (1.20-11.0)	0.055
Water (g)	188.0 (43.0-536.0)	240.5 (21.0-494.0)	274.0 (118.0-620.0)	0.076
Vitamin A (RAE)	104.0 (4.0-386.0)	156.0 (12.0-518.0)	135.0 (7.0-931.0)	.0.261
Retinol (μg)	22.0 (0-235.0)	23.5 (0-371.0)	32.0 (0-173.0)	0.275
Beta carotene (μg)	477.0 (1.0-4,138.0)	1235.0 (4.0-5,058.0)	1352.0 (40.0-10,680.0)	0.055
Vitamin D (μg)	**0.37 (0-5.13)**	**0.36 (0-20.00)**	**~0.0 (0-45.34)**	**0.037**
Vitamin E (mg)	3.00 (1.00-47.0)	7.50 (1.00-36.0)	4.00 (1.00-13.0)	0.270
Vitamin K (μg)	**12.0 (0-364.0)**	**60.5 (0-612.0)**	**68.0 (6.00-1093.0)**	**0.014**
Vitamin C (mg)	**13.0 (0-76.0)**	**28.5 (0-146.0)**	**55.0 (3.0-215.0)**	**< 0.001**
Thiamine (mg)	0.56 (0.20-2.01)	0.58 (0.04-1.92)	0.57 (0.12-1.78)	0.957
Riboflavin (mg)	**0.50 (0.10-1.60)**	**0.45 (0.10-1.60)**	**0.40 (0.10-1.10)**	**0.041**
Niacin (mg)	**6.60 (1.60-16.40)**	**4.20 (0.20-13.40)**	**3.00 (0.90-21.30)**	**0.009**
Vitamin B_6 (mg)	0.50 (0.10-1.80)	0.50 (0.0-1.60)	0.40 (0.20-1.50)	0.131
Folic acid (μg)	106.0 (14.0-418.0)	176.5 (15.0-806.0)	153.0 (35.0-698.0)	0.123
Vitamin B_{12} (μg)	**0.80 (0.10-5.00)**	**0.95 (0-13.2)**	**0.20 (0-8.40)**	**0.002**
Pantothenic acid (mg)	**1.40 (0.10-4.00)**	**1.30 (0.10-2.60)**	**0.50 (0.10-1.60)**	**< 0.001**
Biotin (μg)	~0.0 (0-3.50)	~0.0 (0-4.08)	~0.0 (0-9.00)	0.249
Calcium (mg)	**89.0 (22.0-289.0)**	**118.0 (27.0-427.0)**	**130.0 (28.0-723.0)**	**0.035**
Calcium, plant (mg)	**35.0 (14.0-243.0)**	**86.5 (2.0-415.0)**	**93.0 (28.0-546.0)**	**< 0.001**
Calcium, meat (mg)	33.0 (0-259.0)	30.0 (0-210.0)	13.0 (0-271.0)	0.107
Phosphorous (mg)	406.0 (106.0-1,147.0)	362.0 (51.0-1,216.0)	353.0 (51.0-921.0)	0.356
Sodium (mg)	**1104.0 (167.0-3,048.0)**	**1021.5 (117.0-3,557.0)**	**351.0 (13.0-3,442.0)**	**< 0.001**
Chloride (mg)	16.1 (0-1,712.0)	13.8 (0-253.8)	3.1 (0-317.2)	0.124
Potassium (mg)	782.0 (175.0-2,047.0)	767.0 (58.0-3,779.0)	793.0 (232.0-1,982.0)	0.425
Magnesium (mg)	33.0 (3.00-160.0)	34.0 (2.00-270.0)	40.0 (6.00-141.0)	0.219
Iron (mg)	3.70 (1.40-10.40)	4.55 (0.30-18.30)	4.60 (0.70-15.60)	0.862
Plant iron (mg)	2.40 (0.50-7.70)	3.45 (0.10-17.00)	3.50 (0.70-10.50)	0.059
Animal iron (mg)	**1.70 (0.20-5.20)**	**1.15 (0-7.00)**	**0.10 (0-5.20)**	**< 0.001**
Zinc (mg)	**3.8 (0.80-12.6)**	**3.3 (0.30-12.6)**	**2.0 (0.40-6.3)**	**0.006**
Copper (μg)	198.0 (25.0-486.0)	211.0 (20.0-1,340.0)	169.0 (19.0-479.0)	0.303
Fluorine (mg)	~0.0 (0-0.05)	~0.0 (0-0.05)	~0.0 (0-0.08)	0.964
Manganese (mg)	0.38 (0.07-1.06)	0.62 (0.01-4.92)	0.49 (0.07-1.84)	0.656
Iodine (μg)	4.90 (0-590.5)	6.30 (0-580.0)	2.30 (0-50.40)	0.131
Selenium (μg)	**29.6 (0.10-137.2)**	**20.6 (1.00-71.6)**	**13.6 (0.60-121.9)**	**0.018**
Cobalt (μg)	~0.0	~0.0 (0-56.3)	~0.0 (0-0.07)	0.961
Molybdenum (μg)	~0.0 (0-4.08)	0.10 (0-12.6)	0.15 (0-2.79)	0.125
Cholesterol (mg)	**130.0 (7.00-495.0)**	**84.0 (0-493.0)**	**17.0 (0-268.0)**	**< 0.001**

* Rates of proportions contributing total calories of meals.
ACFS, Anti-cancer food scoring system; RAE, Retinol Activity Equivalent.
ACFS grade S, ideal for cancer prevention; A, good for cancer prevention; B, might have anticancer potential; C, difficult to be regarded as preventive or carcinogenic; D, might be against cancer prevention; E, probably against cancer prevention.

Statistical analyses

Univariate analyses were performed using the Jonckheere-Terpstra test to identify trends among ACFS grade subgroups. The variables with P values of < 0.05 in the Jonckheere-Terpstra test were included in the multivariate analyses. Among the variables, possibly duplicated variables (e.g., total fat and animal fat, total fiber and water-soluble fiber, calcium and plant calcium) were filtered to be included in the multivariate analysis using the following criteria prioritized in numerical order: 1) the variable with higher statistical significance; 2) the specific variable rather than the general one. Simple nutritional or proportional values including total calories and carbohydrate, lipid, and protein rates contributing to the total calories of meals were not included in the multivariate analysis. Multivariate analyses were performed via multiple regression analyses, using the backward elimination method. The probabilities of removal and entry were 0.10 and 0.05, respectively. Standardized β coefficients and non-standardized β coefficients were presented to identify the comparative significance of each variable. All statistical tests were performed using SPSS version 23.0 (IBM Corp., Armonk, NY, USA).

RESULTS

Nutrition profiles and ACFS scores

A total of 88 international recipes, including 15 Korean home-dining, 15 Korean out-dining, 10 Chinese, 20 Mediterranean, 10 vegetarian, and 18 Western recipes, were included in this study and analyzed. The number of recipes in the highest anti-carcinogenic category (S grade) was 13 (14.8%), followed by 20 in A grade (22.7%), 21 in B grade (23.9%), 15 in C grade (17.0%), 16 in D grade (18.2%), and 3 in E grade (3.4%). All 13 S grade recipes belonged to vegetarian or Mediterranean recipes. The median ACFS grades, derived from ingredient scores after considering the harmful cooking methods, were B, C, B, A, S, and D for Korean home-dining, Korean out-dining, Chinese, Mediterranean, vegetarian, and Western recipes, respectively.

For all the 88 recipes, the ingredient scores ranged from 132 to 487 with a median value of 320 and the energy values ranged from 137 to 1,643 kcal with a median value of 484 kcal. The median ingredient scores of Korean home-dining, Korean out-dining, Chinese, Mediterranean, vegetarian, and Western recipes were 310 (range: 192-407), 298 (200-368), 359 (132-487), 367 (229-443), 432 (394-459), and 201 (141-321), respectively; median energy values in kcal were 708 (350-1643), 498 (274-1364), 335 (146-582), 504 (180-1233), 298 (248-406), and 555 (137-1347), respectively.

The names of the recipes, ingredient scores, ACFS grades, calories, and brief nutritional profiles are presented in Table 2. The full nutritional profile is described in Supplementary file S1.

Nutritional analyses

For univariate analysis, we categorized the 6 ACFS grades into 3 groups: S and A; B and C; D and E. In the analysis, the following factors were correlated with the ACFS grade groups ($P < 0.05$): total calories, total fat, animal fat, animal protein, total protein, vitamin D, riboflavin, niacin, vitamin B_{12}, pantothenic acid, sodium, animal iron, zinc, selenium, and cholesterol (negative trends); carbohydrate rate, fiber, water-soluble fiber, vitamin K, vitamin C, and plant calcium (positive trends). The results of the univariate analysis are summarized in Table 3. Multivariate analysis was performed on factors found to be significant in the univariate analysis. The following variables were included: animal fat, animal protein, vitamin D, riboflavin, niacin, vitamin B_{12}, pantothenic acid, sodium, animal iron, zinc, selenium, cholesterol, fiber, vitamin K, vitamin C, and plant calcium. For multivariate analysis, the 6 ACFS grades and the quantitative amounts of nutrition profiles were used. Six profiles were found to be statistically significant: animal fat (standardized β = -0.330, P = 0.020), animal iron (standardized β = -0.345, P = 0.021), and niacin (standardized β = -0.359, P = 0.004) (negative trends); fiber (standardized β = 0.183, P = 0.034), animal protein (standardized β = 0.525, P = 0.006), and vitamin C (standardized β = 0.420, P < 0.001) (positive trends). Two profiles showed non-significant negative trends (P < 0.1): pantothenic acid (standardized β = -0.192, P = 0.062) and sodium (standardized β = -0.175, P = 0.077). Vitamin B_{12} showed a non-significant positive trend (standardized β = 0.193, P = 0.074). Each standardized β value represented the relative significance of each variable. These results are summarized in Table 4.

Table 4. Result of the multivariate analysis on statistically significant factors obtained from the univariate analysis.

	non-standardized		standardized	
	β	SE	β	P
Significant factors				
Animal fat	-0.030	0.013	-0.330	0.020
Animal iron	-0.364	0.155	-0.345	0.021
Niacin	-0.138	0.047	-0.359	0.004
Fiber	0.029	0.013	0.183	0.034
Animal protein	0.037	0.013	0.525	0.006
Vitamin C	0.013	0.003	0.420	< 0.001
Non-significant trends				
Pantothenic acid	-0.349	0.184	-0.192	0.062
Sodium	0	0	-0.175	0.077
Vitamin B_{12}	0.123	0.068	0.193	0.074

SE: standard error

DISCUSSION

The present study demonstrated that the ACFS calculation model was significantly associated with known healthy and unhealthy nutritional factors. Univariate analysis showed that the ACFS model was strongly negatively correlated with factors such as animal fat (P < 0.001), sodium (P < 0.001), and cholesterol (P < 0.001), which are generally considered to be harmful to health, and strongly positively correlated with factors such as fiber (P < 0.001), vitamin C (P < 0.001), and plant calcium (P < 0.002), which are considered beneficial.

Multivariate analysis showed that the ACFS model is negatively correlated with animal fat, animal iron, and niacin and positively correlated with fiber, vitamin C, and animal protein (Ps < 0.05). Pantothenic acid and sodium had non-significant negative trends, while vitamin B_{12} showed a positive trend (Ps < 0.1).

In the recently updated WCRF and AICR third expert report, red meat consumption showed strong evidence of increased risk of colorectal cancer and limited evidence of increased risks of nasopharyngeal, lung, and pancreatic cancers [18]. The most well-known causes of cancer related to red meat consumption are heterocyclic amines and polycyclic aromatic hydrocarbons, which are carcinogens that are produced on high-temperature cooking [19]. Besides, saturated fat itself has been known to be related to the risk of cancers, including breast, lung, and colorectal cancers [20-22]. This evidence aligns with our study results concerning animal fat. The iron components in animal products were found to be associated with the ACFS grade in our study. Heme iron, which is abundant in red meat, was known to be related to tumorigenesis by stimulating the endogenous formation of N-nitroso compounds [19]. Body iron stores, which were assessed by serum iron and transferrin saturation of total iron-binding capacity, were reported to increase the incidence of cancer in large population studies [23,24], although these results need to be verified by studies with more nutritional perspectives.

Animal protein was found to have a positive relationship with the ACFS grade in multivariate analysis, which reflects its anti-carcinogenic potential. Interestingly, animal protein showed a negative trend in the univariate analysis but reversed to have a positive trend in the multivariate analysis. We hypothesized that animal protein from poultry and fish might affect these results and the carcinogenic effect of meat might be more related to other components such as fat or iron, although further studies are warranted. Poultry intake was reported to be inversely associated with colorectal cancer risk in a recent meta-analysis, with a risk ratio (RR) of 0.89 (95% confidence interval [CI], 0.81-0.97) for a 50 g/day increase uptake of poultry [25]. A meta-analysis study reported an inverse relationship between poultry intake and lung cancer (RR 0.91, 95% CI: 0.85-0.97) [26], and a population-based case control study showed a similar relationship between pancreatic cancer and poultry intake (odds ratio: 0.7, 95% CI: 0.5-1.0) [27]. Fish intake was reported to have limited-suggestive evidence of decreasing the risk of liver and colorectal cancers in the third expert report of the WCRF and the AICR [18]. In a meta-analysis, the pooled RR of the highest fish intake category compared to the lowest fish intake category was 0.88 (95% CI: 0.78-1.00) for colorectal cancer incidence [28]. For liver cancer, the pooled RR for the highest fish intake quartile was 0.82 (95% CI: 0.71-0.94), as per a recent meta-analysis study [29]. Unfortunately, we cannot fully explain the results of the meta-analyses with regard to the mechanisms, as the mechanisms are not fully understood yet and are masked by confounding factors [25,30]. We hope that future studies investigating the cancer protective mechanisms of poultry and fish can explain these results and show a correlation with ACFS.

Foods containing dietary fiber had strong protective evidence for colorectal cancer in the third expert report of the WCRF and the AICR [31]. In humans, fibers can be fermented and metabolized by the colonic microflora, forming short-chain fatty acids, such as butyrate, which have an anti-proliferative effect on colon cancer. Additionally, fibers can reduce the transit time of fecal bulk and lessen the interaction between fecal mutagens and colonic mucosa [32,33]. Dietary fiber was also associated with decreased risk of breast cancer in a meta-analysis, with an RR of 0.95 per 10 g/day intake [34]. The European Prospective Investigation into Cancer and Nutrition study, which included a prospective cohort of > 500,000, reported that colorectal, breast, and liver cancers were inversely associated with dietary fiber intake [35]. Vitamin C has been known to prevent cancer and proven to have a protective effect on esophageal, laryngeal, oral cavity, pancreatic, stomach, rectal, breast, and cervical cancers, which are strongly consistent with the results of the previous meta-analyses [36,37]. It was also reported to have limited -suggestive evidence of decreasing the risks of colorectal and lung cancers in the third expert report of the WCRF and the AICR [31].

The relationship between niacin intake and cancer risk is largely unexplored. Although there is some *in vivo* evidence that niacin status influences carcinogenesis in a tissue-specific manner, evidence from human studies is lacking [38]. In a recent clinical study, niacin intake was inversely associated with squamous cell carcinoma of the skin but showed a positive relationship with basal cell carcinoma of the skin [39]. Since ACFS is based on meal recipes (not nutritional components), correlation with niacin, which is abundant both in plant foods (e.g., peas and barley have high ACFS score) and red meats (low ACFS scores), might not be robust. Future clinical studies evaluating the anti-cancer or carcinogenic effects of niacin are necessary.

Among the factors with non-significant trends, vitamin B_{12} was shown to have an inverse relationship with cancer risk in recent studies. A dose-response relationship between dietary intake of vitamin B_{12} and decreased risk of colorectal cancer was shown in a recent meta-analysis (pooled RR: 091, 95% CI: 0.86-0.98) [40]. A recent case-control study revealed that low vitamin B_{12} concentration was associated with a 5.8-fold higher risk of non-cardia gastric cancer [41]. Another study also found a significant association between low levels of plasma vitamin B_{12} and hepatocellular carcinoma risk (odds ratio: 2.01, 95% CI: 1.02-3.98) [42]. Sodium was also negatively associated with the ACFS grade with non-significant trends. The positive association between sodium and cancer is most well-known for gastric cancer [43], and the third expert report by the WCRF and the AICR also reported strong evidence between Cantonese-style salted fish and nasopharyngeal cancer [44]. Although relevant effects of pantothenic acid have not been extensively studied in the literature, Hutschenreuther *et al.* [45] reported that the aggressiveness of tumor cells might be related to pantothenic acid in a cell-line study. This component should be investigated in future to explain our results.

It has long been necessary to categorize and quantify factors that can prevent or increase the risk of cancer. The International Agency for Research on Cancer systematically classifies substances that may or may not be carcinogenic [46]. The expert reports of the WCRF and the AICR, probably the most comprehensive review regarding cancer prevention, diet, and lifestyle, have proved their clinical efficacy in recent prospective trials [7]. Our ACFS model systematically analyzed the literature regarding diet and cancer prevention, based on the classification system from the WCRF and AICR [47], and enabled quantitative anti-cancer scoring of a wide-range of everyday meals. Consequently, our model allows everyone without medical or nutritional expertise to obtain an evidence-based anti-cancer or carcinogenic score of their meals.

Although several models have already been published to assess the health index of food, our model is unique because of the following reasons. Scoring methods such as aggregate nutrient density index (ANDI) [48] and NuVal® [49], which are developed in the US and commonly used, are composed of assessments focusing on overall health, while the ACFS focuses on cancer prevention or carcinogenicity. Additionally, the ACFS evaluates complete meals actually consumed in daily life, while the ANDI and NuVal evaluate food components. Healthy Eating Index (HEI) [50] and Dietary Quality Index (DQI) [51] are tools for evaluating meals rather than individual food components. However, these tools do not focus on cancer but on overall health or known nutritional expertise. Hence, the ACFS model is unique in evaluating daily meals, yielding indexes focused on cancer prevention and carcinogenicity.

The purpose of the present study was to provide a nutritional basis for the efficacy of the ACFS calculation model. Although ACFS was based on a comprehensive systematic review, there is a lack of substantive evidence to demonstrate its efficacy. This study could facilitate the design of research demonstrating the clinical utility of ACFS. Although we included 88 recipes from 6 international categories, probably the number of samples should be further increased. Representing each diet category with 10-20 recipes also has limitations. We performed fairly objective selections of representative foods for Asian recipes, but we were forced to rely mainly on the author's discussion in the corresponding websites for the selection of Western meals. Along with the clinical study design, to enhancement of nutritional reliability using larger validation with more number of international recipes will be the subject of our future studies.

We have shown that the ACFS grade generally corresponds with commonly known anti-cancer or carcinogenic factors. Although the effect of some factors needs to be elucidated through additional studies, the ACFS grade has been well correlated with factors such as fiber, vitamin C, vitamin B_{12}, sodium, animal fat, and iron. Hence, our calculation model could be named ACFS 2.0, reflecting the newly drawn reliability of this study. Future clinical studies along with wider validation are warranted to firmly prove the utility of the model.

CONFLICT OF INTEREST

The author declares no potential conflicts of interests.

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