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Eating frequency is inversely associated with BMI, waist circumference and the proportion of body fat in Korean adults when diet quality is high, but not when it is low: analysis of the Fourth Korea National Health and Nutrition Examination Survey (KNHANES IV)

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Abstract

The role of eating frequency (EF) in obesity development has been debated, and few studies have investigated Asian populations. Diet quality might affect the association between EF and obesity. Therefore, we investigated the association between EF and obesity indicators in a representative sample of Korean adults with consideration to diet quality. This cross-sectional study used data of 6951 participants aged 19–93 years (male 49·8 %, female 50·2 %) from the Fourth Korean National Health and Nutrition Examination Survey. EF was assessed using a questionnaire, and diet quality was defined as mean adequacy ratio (MAR). To explore the association between EF and obesity indicators, we used multiple linear regression analyses with and without interaction terms between diet quality and EF. EF was inversely associated with each obesity indicator, including body fat percentage (BF%), BMI and waist circumference (WC), showing a significant linear trend ($P < 0.001$ for BF%, WC and BMI). In addition, the association between EF and each obesity indicator was significantly altered according to diet quality (P value of the interaction term EF × diet quality = 0·008 in the regression model for BF%, <0·001 for BMI and 0·043 for WC). In the stratified analyses according to diet quality, EF had a significant inverse association with BF%, WC and BMI in the high diet quality groups, but not in the low diet quality groups. This study suggests that EF is inversely associated with the obesity indicators when diet quality is high, but not when it is low in Korean adults.

Key words: Diet quality: Eating frequency: Body fat: Obesity

Obesity has become a global epidemic health problem because it is a highly prevalent and major risk factor for CVD and chronic diseases including cancer[1]. The recent global estimates of the WHO revealed that about 13 % (11 % of men and 15 % of women) of the world's adult population were obese in 2016, and the worldwide prevalence of obesity increased nearly by 30% between 1980 and 2013[2,3]. The prevalence of obesity has also been increasing in Asian countries, including Korea[4]. The obesity prevalence in Korean adults increased from 26·0 to 36·3 % in men and from 26·5 to 27·6 % in women between 1998 and 2009[5].

Diet is a major lifestyle factor contributing to the development of obesity, and it is modifiable if properly managed[6]. Among various dietary factors, eating frequency (EF) has been suggested as a modifiable aspect of dietary behaviour that may influence the risk of obesity[7,8]. EF is usually defined as the sum of the number of meals and snacks consumed per day[7,9]. There have been many previous studies that have investigated the relationship between EF and obesity, but the results have been inconsistent thus far. A previous prospective study reported that decreased EF is predictive of greater 10-year increases in BMI and waist circumference (WC)[10]. A cross-sectional study also suggested that higher EF is associated with lower WC and reduced cardiometabolic risk factors, including fasting glucose, total cholesterol, LDL cholesterol and TAG, and that these associations are mediated by WC[11]. Another study revealed that increased EF is related to lower BMI and WC in overweight Hispanic youth[8]. In contrast, others reported the positive association between EF and obesity[12], or they could not detect any association[13,14]. In particular, the body fat percentage (BF%) showed no association with EF[15], or even a positive correlation with EF[16]. However, the factors that lead to such discrepancies between studies have not yet been clarified.

Abbreviations: BF%, body fat percentage; EF, eating frequency; KNHANES IV, Fourth Korea National Health and Nutrition Examination Survey; MAR, mean adequacy ratio; WC, waist circumference.

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Previous studies have shown that a higher intake of fruits, vegetables, nuts and whole grains may play a protective role against obesity[17]. In contrast, obesity results from a higher intake of sweets, refined bread and high-energy density food[17], which can induce an excessive energy intake (EI)[18]. Korea has experienced a nutrition transition over recent years[19]. Consumption of traditional Korean diet, which is a low-fat and high-vegetable diet, has decreased, whereas consumption of bread, meat and seafood has increased, as Korea has become more westernised[19]. These changes have affected the increase of obesity prevalence[20,21]. Given that the diet quality may also play a role in the development of obesity[22,23], it can be speculated that the relationship between EF and obesity might be modified by diet quality, but this issue has not been studied thus far.

Furthermore, few studies have covered the relationship between EF and obesity in Asian populations[24,25], although the typical Asian lifestyle, including diet and eating habits, differs from the typical Western lifestyle. Accordingly, the effect of EF on obesity may differ between Asian and Western populations. Therefore, in this study, we aimed to investigate the association between EF and obesity indicators including BMI, WC and BF% in a representative sample of the Korean adult population, and to determine whether the association between EF and the obesity indicators changes with diet quality.

Methods

Study population

This cross-sectional study was based on data from the 2nd and 3rd years of the Fourth Korea National Health and Nutrition Examination Survey (KNHANES IV), which was conducted by the Korean Centers for Disease Control and Prevention from 2007 to 2009. KNHANES IV is a nationwide representative study, and its target population is non-institutionalised civilians in the Republic of Korea. The sample frame was determined based on the 2005 population and housing census, and the representative households were selected using a stratified multistage clustered probability sampling design. However, family members younger than 1 year in the selected households were excluded from the survey. The survey was composed of four parts: the Health Interview Survey, the Health Behaviour Survey, the Health Examination Survey and the Nutrition Survey. All participants signed an informed consent form and the protocol was approved by the Institutional Review Board of the Korean Centers for Disease Control. The details regarding survey design and methods are specified elsewhere[26–30].

In the 2008 and 2009 KNHANES IV, 9744 and 10 533 individuals participated, respectively. Of the 20 277 participants, we sequentially excluded 5206 subjects younger than 19 years old; 4480 subjects without measurements for BF%, WC or BMI; 1293 subjects without nutritional data including meal frequency, snack frequency and nutrient intake; 261 subjects without data for socio-economic or lifestyle variables such as household income, education level, smoking status, frequency of alcohol consumption, physical activity, frequency of resistance exercise, stress level and depressed mood; and 2086 subjects who answered that their meal frequency was zero or that they did not eat a meal or a snack as per usual on the survey day. The data of the remaining 6951 participants (aged 19–93 years) were analysed in this study (Fig. 1).

Measurement of variables

Measurement of obesity indicators. As indices of obesity, we used BF% measured by dual-energy X-ray absorptiometry (DXA), as well as WC and BMI. Trained medical staff measured height and weight by 0·1-cm units and 0·1-kg units, respectively, according to the standardised procedures at mobile examination centres. BMI was calculated as weight divided by height squared (kg/m^2). WC was measured according to the WHO guideline to the nearest 0·1 cm in a horizontal plane at the level of the midpoint between the iliac crest and the costal margin at the end of a normal expiration[31]. Body composition status (i.e. BF%) was measured by DXA (Discovery-W™; Hologic).

Eating frequency and nutritional measurements. EF was defined as the sum of the number of meals and snacks eaten per day as previously described[32,33]. Meal frequency was assessed using the following question: ‘Did you eat breakfast/lunch/dinner yesterday?’ Snack frequency was estimated using the following question: ‘How many times do you eat snacks a day?’ Although these questions have not been formally validated as measures of snack and meal frequency, similar questions have been used in other studies[32,34,35]. Meal frequency was classified as one, two or three meals per day; snack frequency was classified as none, one, two or three snacks per day; and EF was categorised as less than three, three, four and five or more per day, as previously described[32]. Categories of EF were determined by considering the distribution of each measure in the study population, ensuring adequate number in each group.

Daily energy and nutrient intake, including total EI (kJ/d (kcal/d)), fat intake (g/d), carbohydrate intake (g/d) and protein intake (g/d), were assessed on the basis of the results of the nutrition survey of KNHANES IV[36]. The nutrition survey was conducted in person by trained dietary interviewers, who visited participants’ homes and asked the respondents to remember in detail all the food and drinks they consumed during a period of time in the recent past (usually in the previous 24 hours). The 24-h recall method is a cost-effective and applicable dietary assessment for characterising the average population intake[37]. Plastic food models, a set of measuring guides (including bowls, plates, earthen pots, jars, measuring spoons, glasses, mugs and coffee cups), shape charts (circle, ellipse, wedge, triangle and rectangle) and rulers were used to help the respondent report the volume and dimensions of dishes consumed, which was converted to weight using the food portion/weight database[38]. Next, the amount of each food ingredient included in a dish was estimated using the recipe database by Korea Health Industry Development Institute[39]. Finally, the energy and nutrient intake was calculated using the seventh edition of the food composition table from the Korean National Academy of Agricultural Science[40]. The results of these calculations are provided on the website of the Korea Centers for Disease Control and Prevention[41].

Estimated average requirement (EAR) of daily energy was obtained from Dietary Reference Intakes for Koreans 2010

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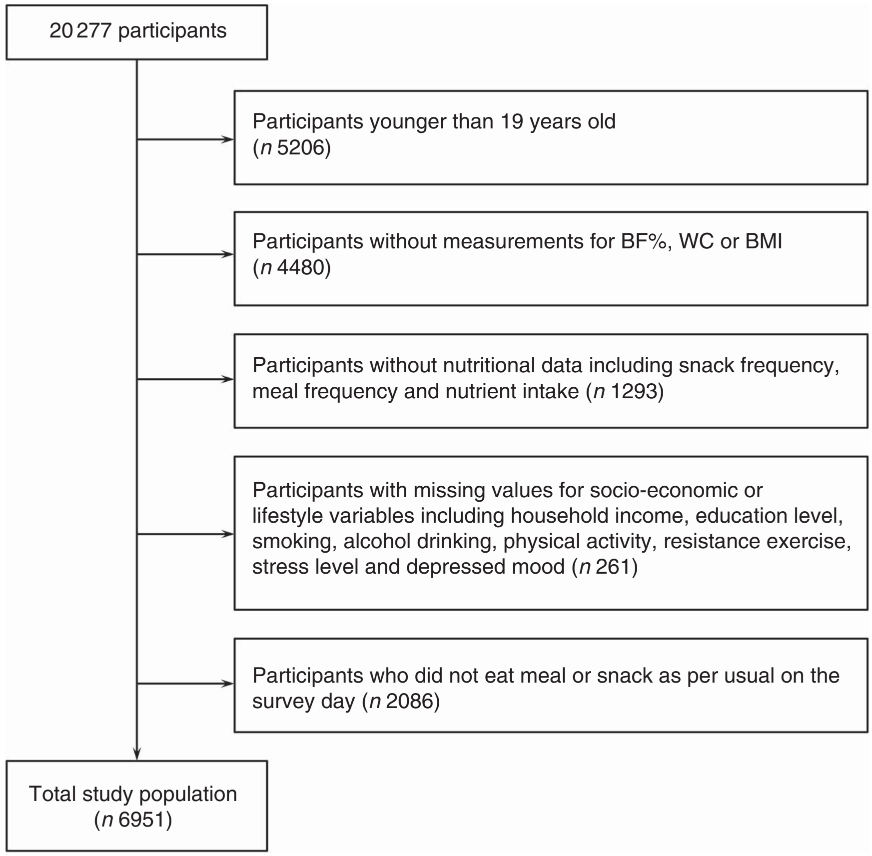

Fig. 1. Study population. BF%, body fat percentage; WC, waist circumference.

(online Supplementary Table S1)[42]. The nutrient adequacy ratio (NAR) was calculated for each of nine nutrients (protein, Ca, P, Fe, vitamin A, thiamine, riboflavin, niacin and vitamin C) using the following formula: NAR = subject's daily intake of a nutrient/ recommended nutrition intake according to sex and age of that nutrient. The nine NAR values were then averaged to yield a mean adequacy ratio (MAR)[43]. The MAR provides an index of the overall diet quality. A high MAR implies a high-quality diet[44].

Measurement of demographic, socio-economic and lifestyle-related variables. Data on the age group (categorised as 19–29, 30–39, 40–49, 50–59, 60–69 and 70 or more years), sex (male/female), smoking status (categorised as never, past (had smoked ≥100 cigarettes during their lifetime but not smoking currently) and current smoker (had smoked ≥100 cigarettes and still smoking)), alcohol drinking frequency (less than once per month, once per month, two to four times per month, two to three times per week and four times or more per week), education level (elementary school/middle school/high school/university), resistance exercise frequency (none, once per week, twice per week, three times per week, four times per week and five times or more per week) and physical activity assessed by the International Physical Activity Questionnaire scores (metabolic equivalent of task-min per week)[45] were acquired by the Health Interview Survey. The household income was estimated using the following question: 'What is the approximate total household income for the past 1 year, including wages, real-estate income, pensions, interest, government subsidies, allowances for relatives or children and so on?' Thereafter, the study population was divided into quartiles (low/mid-low/mid-high/high) on the basis of the total household income. The depressed mood (yes/no) was determined using the following question: 'Have you ever felt sad or desperate for 2 consecutive weeks during the past 1 year so that your daily life is hindered?' The stress level (rare/a little/much/ too much) was assessed using the following question: 'How stressed out do you feel in your daily life?'

Statistical analysis

All statistical analyses were conducted using statistical software R version 3.3.1 (The R Foundation for Statistical Computing). As the KNHANES IV adopted a stratified multistage clustered probability sampling design, the survey package for R was used to account for cluster effects and sampling weights[46,47]. The study data included a total of 307 clusters, and three to 45 subjects were included in each cluster. All of the results are presented as weighted values. The general characteristics of the study population are presented as means with their standard errors (SE) for continuous variables and percentages (%) with their standard errors for categorical variables. The nutritional characteristics are also presented as mean values with their standard errors. We explored the association between EF and each obesity indicator (BF%, BMI and WC) using multiple linear regression analyses for complex survey design[48]. To prevent multicollinearity between variables, we confirmed that all variance inflation factors are smaller than 10. Because the distributions of BF%, BMI and WC were not symmetric, the Box–Cox power transformation was used to make them more normally distributed. The parameters for the transformation of BF%, BMI and WC were 1·124397, −0·04895731 and 0·4656249, respectively. The design effects for the transformed variables from BF%, BMI and WC were 2·6549, 1·7001 and 2·7373, respectively. The transformed variables were used as dependent variables in the multiple regression analyses, and the predicted marginal means and 95 % CI for the dependent variables were estimated in each EF group. From those, the adjusted means and 95 % CI for BF%, BMI and WC were calculated as inverses of the Box–Cox transformation. We also tested for a linear trend of the dependent variables across EF groups after adjusting for potential confounders. The confounding variables were chosen on the basis of the results of previous studies, and included age group[49], sex[50], smoking status[51], alcohol drinking frequency[49], resistance

Table 1. General characteristics of the study population
(Mean values and percentages with their standard errors)

	EF < 3 (*n* 539)		EF = 3 (*n* 2413)		EF = 4 (*n* 2564)		EF ≥ 5 (*n* 1435)		Total (*n* 6951)	
	Mean/%	SE	Mean/%	SE	Mean/%	SE	Mean/%	SE	Mean/%	SE
Body fat percentage (%)*	26·433	0·366	26·271	0·232	26·811	0·203	27·510	0·264	26·730	0·152
BMI (kg/m^2)*	23·646	0·154	23·691	0·086	23·524	0·084	23·132	0·105	23·515	0·052
Waist circumference (cm)*	81·113	0·472	81·668	0·292	80·918	0·272	79·329	0·333	80·876	0·196
Age group (years)†										
19–29	27·96	2·471	17·48	1·426	15·13	1·145	13·49	1·288	16·84	0·892
30–39	27·22	2·170	17·75	1·144	21·42	1·194	21·15	1·580	20·67	0·881
40–49	19·26	1·873	22·23	1·141	23·18	1·081	22·72	1·431	22·39	0·749
50–59	13·88	1·595	17·57	1·014	18·40	0·943	20·97	1·309	18·20	0·638
60–69	6·69	0·972	12·72	0·797	12·45	0·724	12·07	0·935	11·91	0·497
70 or more	4·99	0·889	12·25	0·808	9·41	0·623	9·59	0·890	9·99	0·477
Sex†										
Male	57·32	2·412	56·15	1·138	48·84	1·137	37·24	1·479	49·84	0·615
Female	42·68	2·412	43·85	1·138	51·16	1·137	62·76	1·479	50·16	0·615
Smoking status†										
Never smoker	43·69	2·391	49·82	1·188	58·46	1·159	68·79	1·477	56·16	0·697
Past smoker	12·82	1·813	19·20	0·943	20·37	0·971	15·80	1·156	18·34	0·541
Current smoker	43·49	2·587	30·99	1·208	21·17	1·050	15·40	1·181	25·50	0·728
Alcohol drinking frequency†										
Less than once/month	31·48	2·262	39·79	1·218	43·90	1·141	52·16	1·549	42·95	0·733
Once per month	9·90	1·518	10·49	0·759	11·55	0·752	11·38	0·929	11·00	0·435
2–4 times/month	26·18	2·480	23·95	1·171	24·08	0·986	19·45	1·310	23·32	0·610
2–3 times/week	23·13	2·265	17·71	1·082	13·56	0·832	11·67	0·968	15·51	0·585
4 times or more/week	9·31	1·530	8·05	0·599	6·91	0·586	5·35	0·714	7·22	0·359
Physical activity (MET-min/week)*	2365·565	171·286	2453·952	70·835	25612·32	71·545	2689·099	105·181	2531·395	48·972
Resistance exercise frequency†										
None	69·02	2·393	71·34	1·258	70·54	1·161	72·48	1·441	71·05	0·726
Once per week	9·20	1·648	6·66	0·648	6·64	0·630	5·04	0·702	6·57	0·396
2 times/week	6·27	1·405	7·13	0·759	7·30	0·651	7·43	0·837	7·17	0·371
3 times/week	6·26	1·461	5·64	0·630	5·66	0·529	6·43	0·844	5·87	0·368
4 times/week	4·15	1·110	2·43	0·435	3·37	0·465	2·05	0·407	2·86	0·264
5 times or more/week	5·11	1·129	6·80	0·608	6·48	0·606	6·57	0·742	6·48	0·372
Stress level†										
Rare	12·37	1·814	15·01	0·863	15·60	0·887	14·46	1·042	14·86	0·535
A little	49·24	2·456	55·31	1·172	57·93	1·195	59·59	1·573	56·53	0·728
Much	30·25	2·213	23·71	1·131	22·26	0·918	21·51	1·363	23·37	0·614
Too much	8·13	1·419	5·97	0·561	4·21	0·438	4·44	0·635	5·23	0·294
Depressed mood†										
No	82·86	1·867	85·57	0·880	86·59	0·798	85·79	1·067	85·73	0·536
Yes	17·14	1·867	14·43	0·880	13·41	0·798	14·21	1·067	14·27	0·536
Education level†										
Elementary school	19·35	1·876	26·98	1·293	20·49	1·062	19·86	1·323	22·46	0·805
Middle school	6·55	1·157	12·07	0·736	11·06	0·744	11·11	0·870	10·98	0·460
High school	43·70	2·666	37·62	1·514	39·89	1·319	39·47	1·778	39·40	0·953
University	30·40	2·554	23·33	1·389	28·57	1·390	29·57	1·674	27·16	1·041
Household income†										
Low	16·42	1·937	21·14	1·211	15·13	0·926	13·20	1·115	16·91	0·756
Mid-low	28·26	2·491	26·15	1·292	24·56	1·235	23·84	1·468	25·31	0·931
Mid-high	31·26	2·636	28·68	1·235	29·12	1·324	30·72	1·719	29·49	0·921
High	24·06	2·739	24·03	1·333	31·19	1·683	32·24	1·987	28·28	1·210

EF, eating frequency; MET, metabolic equivalent of task.
* Means and standard errors using sampling weight for complex sample.
† Percentages and standard errors using sampling weight for complex sample.

exercise frequency[52], physical activity[49], MAR (quartile)[53], EI: EAR ratio[54], depressed mood[55], household income[56], education level[49] and stress level[57]. The same methods were also used to assess whether snack frequency and meal frequency were significantly associated with each obesity indicator. To determine whether the association between obesity indicators and EF, snack frequency and meal frequency changes according to diet quality, we analysed further multiple linear regression models that included all variables listed above and additional interaction terms between diet quality index (MAR quartiles) and EF, snack frequency or meal frequency. Then, the multiple linear regression analyses were repeated for the subgroups stratified by MAR quartile. Statistical significance was defined by a two-tailed $P<0·05$.

Results

General and nutritional characteristics of study participants according to eating frequency groups

EF ranged from 1 to 6, and it was classified as less than three (EF < 3: 9·60 %), three (EF = 3: 33·99 %), four (EF = 4: 36·55 %) and five or more per day (EF ≥ 5: 19·87 %). Mean values of obesity indicators and demographic, health behavioural and socio-economic characteristics according to EF groups are presented in Table 1. Table 2 summarises mean daily intakes of energy, macronutrients and micronutrients, and mean MAR values according to EF groups.

Association between eating frequency and obesity indicators (body fat percentage, BMI and waist circumference)

In the multiple linear regression analyses for survey design with adjustment for covariates, the adjusted means of BF%, BMI and WC were all decreased as EF increased from the low-EF group (EF < 3) to the high-EF group (EF ≥ 5), showing a significant linear trend ($P<0·001$ for BF%, BMI and WC) (Table 3). The highest-EF group (EF ≥ 5) showed statistically significant differences in all obesity indicators (BF%, BMI and WC) compared with all other EF groups (Table 4). As snack frequency increased from zero to three per day, the adjusted means of BF%, BMI and WC were also significantly altered ($P=0·001$ for BF%, 0·002 for BMI and 0·001 for WC). The group having snack twice a day showed significantly lower BF%, BMI and WC compared with the group having snack once a day or the group having no snack. Each obesity indicator was also significantly changed according to meal frequency ($P=0·002$ for BF%, <0·001 for BMI and 0·036 for WC). The group having meals three times a day showed significantly lower BF%, BMI and WC compared with the group having meals twice a day.

Change in the association between eating frequency and obesity indicators according to diet quality

To assess the diet-quality-associated alteration of the relation between obesity indicators and EF, snack frequency and meal frequency, we analysed multiple linear regression models that included the same variables as above and additional interaction terms between diet quality index (MAR quartiles) and EF, snack frequency or meal frequency. The results showed that the association between EF and each of the three obesity indicators was significantly altered according to diet quality (P value of the interaction term EF × MAR quartile = 0·008 in the regression model for BF%, <0·001 for BMI and 0·043 for WC). In addition, the associations between snack frequency and both BMI and WC were significantly changed according to diet quality, but that between snack frequency and BF% was not (P value of the interaction term snack frequency × MAR quartile = 0·036 in the

Table 2. Nutritional characteristics classified according to eating frequency
(Mean values with their standard errors)

	EF < 3 (*n* 539)		EF = 3 (*n* 2413)		EF = 4 (*n* 2564)		EF ≥ 5 (*n* 1435)		Total (*n* 6951)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Total energy (kJ/d)	6543·776	205·016	7698·56	83·68	8213·192	83·68	8568·832	117·152	7949·6	54·392
Total energy (kcal/d)	1564·854	49·693	1840·200	20·276	1963·843	20·471	2048·800	28·482	1900·409	13·341
Energy intake:EAR ratio*	0·705	0·019	0·864	0·009	0·936	0·008	1·009	0·013	0·904	0·006
Carbohydrate (g/d)	233·980	5·413	302·029	3·018	328·583	3·074	354·145	4·889	315·557	2·082
Fat (g/d)	32·930	1·939	33·983	0·789	37·225	0·815	38·557	1·138	35·975	0·543
Protein (g/d)	56·198	2·192	64·725	0·940	70·014	0·868	71·878	1·225	67·261	0·619
Crude fibre (g/d)	5·346	0·176	6·892	0·114	7·843	0·119	9·074	0·209	7·525	0·088
Ca (mg/d)	364·954	15·529	457·266	7·447	513·940	8·003	574·204	11·750	492·352	5·112
P (mg/d)	900·502	29·277	1097·104	12·713	1194·432	12·050	1267·125	19·536	1147·587	8·556
Fe (mg/d)	10·427	0·421	13·271	0·231	14·867	0·281	17·257	0·530	14·374	0·193
Vitamin A (µg RE/d)	567·607	35·670	693·001	15·272	850·879	28·182	1009·681	48·586	801·583	17·890
Thiamine (mg/d)	0·996	0·036	1·182	0·019	1·275	0·017	1·369	0·030	1·235	0·012
Riboflavin (mg/d)	0·913	0·041	1·057	0·017	1·184	0·017	1·311	0·027	1·140	0·012
Niacin (mg NE/d)	13·012	0·454	15·079	0·230	16·212	0·215	16·372	0·284	15·552	0·153
Vitamin C (mg/d)	70·660	2·815	88·447	1·855	110·362	2·667	129·838	3·587	102·973	1·666
Mean adequacy ratio (%)†	67·871	1·220	77·228	0·463	82·284	0·376	85·525	0·475	79·826	0·318

EF, eating frequency; EAR, estimated average requirement; NAR, nutrient adequacy ratio; RE, retinol equivalents; NE, niacin equivalents.
* EAR was obtained from Dietary Reference Intakes for Koreans 2010.
† Mean adequacy ratio: average of NAR for nine nutrients (protein, Ca, P, Fe, vitamin A, thiamine, riboflavin, niacin, vitamin C). NAR = the subject's daily intake of a nutrient/Korean recommended nutrition intake of that nutrient. All NAR values are truncated at 1·0.

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Table 3. Body fat percentage, BMI and waist circumference according to eating frequency (Adjusted means and 95 % confidence intervals)

		Body fat percentage (%)		BMI (kg/m^2)		Waist circumference (cm)	
n 6951	*n*	Adjusted mean	95 % CI	Adjusted mean	95 % CI	Adjusted mean	95 % CI
Eating frequency*							
<3	539	27·662	27·027, 28·295	23·821	23·461, 24·187	82·218	81·207, 83·237
3	2413	27·077	26·557, 27·595	23·590	23·348, 23·835	81·523	80·806, 82·244
4	2564	26·901	26·395, 27·406	23·447	23·188, 23·709	81·322	80·533, 82·114
≥5	1435	26·343	25·825, 26·861	23·067	22·802, 23·335	80·229	79·416, 81·047
R^2 (adjusted R^2)		0·533	0·530	0·068	0·064	0·186	0·182
P value		<0·001		<0·001		<0·001	
Snack frequency†							
0	2271	27·420	26·756, 28·081	23·857	23·484, 24·236	82·123	81·058, 83·197
1	2928	27·231	26·579, 27·882	23·758	23·391, 24·130	81·705	80·665, 82·752
2	1345	26·793	26·100, 27·483	23·426	23·019, 23·841	80·843	79·649, 82·047
3	407	26·635	25·683, 27·582	23·455	22·904, 24·019	80·892	79·317, 82·484
R^2 (adjusted R^2)		0·533	0·530	0·069	0·064	0·186	0·182
P value		0·001		0·002		0·001	
Meal frequency‡							
1	97	27·219	25·755, 28·672	23·969	23·054, 24·922	81·808	79·267, 84·391
2	1465	27·227	26·667, 27·786	23·651	23·381, 23·923	81·537	80·703, 82·376
3	5389	26·614	26·125, 27·101	23·255	23·024, 23·489	80·827	80·135, 81·522
R^2 (adjusted R^2)		0·533	0·530	0·069	0·064	0·186	0·182
P value		0·002		<0·001		0·036	

* Adjusted for age group, sex, smoking status, alcohol drinking frequency, physical activity, resistance exercise frequency, household income, education level, stress level, mean adequacy ratio (quartile), energy intake:estimated average requirement ratio and depressed mood.
† Adjusted for same variables as in * plus meal frequency.
‡ Adjusted for same variables as in * plus snack frequency.

Table 4. *P* values for pairwise comparisons for body fat percentage, BMI and waist circumference according to eating frequency

	Body fat percentage	BMI	Waist circumference
Eating frequency*			
<3 *v.* 3	0·037	0·203	0·161
<3 *v.* 4	0·006	0·039	0·073
<3 *v.* ≥5	<0·001	<0·001	<0·001
3 *v.* 4	0·349	0·192	0·531
3 *v.* ≥5	<0·001	<0·001	<0·001
4 *v.* ≥5	0·005	0·003	0·002
Snack frequency†			
0 *v.* 1	0·281	0·390	0·201
0 *v.* 2	0·009	0·002	0·002
0 *v.* 3	0·021	0·062	0·045
1 *v.* 2	0·047	0·017	0·019
1 *v.* 3	0·083	0·177	0·183
2 *v.* 3	0·674	0·899	0·939
Meal frequency‡			
1 *v.* 2	0·991	0·495	0·832
1 *v.* 3	0·399	0·112	0·428
2 *v.* 3	<0·001	<0·001	0·042

* Adjusted for age group, sex, smoking status, alcohol drinking frequency, physical activity, resistance exercise frequency, household income, education level, stress level, mean adequacy ratio (quartile), energy intake:estimated average requirement ratio and depressed mood.
† Adjusted for same variables as in * plus meal frequency.
‡ Adjusted for same variables as in * plus snack frequency.

regression model for BMI, 0·004 for WC and 0·105 for BF%). The interaction term meal frequency × MAR quartile was statistically significant only in the regression models for WC ($P = 0·013$ in the regression model for WC, 0·100 for BMI and 0·080 for BF%). Thus, further subgroup analyses were performed to examine the association between EF, snack frequency and meal frequency and obesity indicators for which the interaction terms were significant in each group stratified by MAR quartile.

In the stratified multiple linear regression analyses according to diet quality group, EF showed significant inverse associations with every obesity indicator (BF%, BMI and WC) after adjusting for potential confounders in two higher diet quality groups (the third and fourth quartile of MAR), but not in two lower diet quality groups (the first and second quartile of MAR). In the highest and the second-highest diet quality groups, the adjusted means of BF%, BMI and WC were all decreased as EF increased from the low-EF group (EF < 3) to the high-EF group (EF ≥ 5), showing a significant linear trend. However, in the lowest and the second-lowest diet quality groups, there was no significant linear trend between EF and obesity indicators. The snack frequency was significantly associated with both BMI and WC in the highest diet quality group, with only WC in the second-highest diet quality group and with neither in the lower diet quality groups (the first and second MAR quartile). There was a significant association between meal frequency and WC only in the highest diet quality group, but not in the lower three diet quality groups (Table 5). Table 6 summarises the results of pairwise comparisons for BF%, BMI and WC according to EF in the subgroup analyses stratified by diet quality index.

Discussion

In this study, we found that EF, snack frequency and meal frequency are inversely associated with obesity indicators, namely BF%, BMI and WC, in Korean adults, but some of those relations were altered according to diet quality. When stratified by diet quality, these inverse associations between EF and the

Table 5. Body fat percentage, BMI and waist circumference according to eating frequency stratified by diet quality index
(Adjusted means and 95 % confidence intervals)

	1st quartile (lowest diet quality) (*n* 2024)			2nd quartile (*n* 1755)			3rd quartile (*n* 1648)			4th quartile (highest diet quality) (*n* 1524)		
MAR quartiles	*n*	Adjusted mean	95 % CI	*n*	Adjusted mean	95 % CI	*n*	Adjusted mean	95 % CI	*n*	Adjusted mean	95 % CI
Body fat percentage (%)												
Eating frequency*												
<3	290	27·964	26·987, 28·936	114	27·239	25·998, 28·472	96	28·589	27·109, 30·061	39	27·370	25·415, 29·308
3	879	27·423	26·513, 28·329	649	27·131	26·294, 27·965	497	27·590	26·552, 28·623	388	26·324	25·324, 27·319
4	613	27·623	26·649, 28·593	665	26·682	25·857, 27·504	675	27·309	26·370, 28·243	611	26·082	25·194, 26·966
≥5	242	27·012	26·045, 27·976	327	26·844	25·856, 27·827	380	26·370	25·289, 27·446	486	25·395	24·513, 26·274
R^2 (adjusted R^2)		0·483	0·474		0·531	0·522		0·540	0·530		0·539	0·529
P value		0·196			0·234			<0·001			0·011	
BMI (kg/m²)												
Eating frequency*												
<3	290	23·806	23·214, 24·413	114	23·548	22·775, 24·350	96	23·739	23·028, 24·472	39	24·182	23·176, 25·234
3	879	23·396	22·870, 23·935	649	23·547	23·033, 24·074	497	23·606	23·081, 24·143	388	23·621	23·070, 24·185
4	613	23·654	23·031–24·295	665	23·375	22·854, 23·909	675	23·302	22·839, 23·775	611	23·252	22·763, 23·752
≥5	242	23·160	22·548, 23·789	327	23·285	22·710, 23·875	380	23·080	22·513, 23·662	486	22·720	22·262, 23·188
R^2 (adjusted R^2)		0·074	0·059		0·073	0·056		0·085	0·067		0·111	0·092
P value		0·248			0·308			0·022			<0·001	
Snack frequency†												
0	918	23·637	23·001, 24·291	566	23·516	22·803, 24·251	456	24·067	23·178, 24·992	331	24·322	23·611, 25·055
1	757	23·723	23·043, 24·424	775	23·617	22·875, 24·385	745	23·723	22·912, 24·563	651	23·888	23·220, 24·575
2	277	23·269	22·531, 24·032	325	23·429	22·655, 24·232	347	23·751	22·880, 24·657	396	23·347	22·727, 23·985
3	72	23·526	22·172, 24·966	89	23·521	22·540, 24·546	100	23·172	21·994, 24·416	146	23·631	22·888, 24·399
R^2 (adjusted R^2)		0·073	0·057		0·076	0·057		0·087	0·067		0·117	0·096
P value		0·360			0·851			0·069			0·003	
Waist circumference (cm)												
Eating frequency*												
<3	290	82·240	80·585, 83·913	114	80·846	78·678, 83·046	96	83·166	81·261, 85·094	39	83·453	80·609, 86·350
3	879	81·196	79·652, 82·757	649	81·072	79·619, 82·539	497	81·885	80·406, 83·378	388	81·726	80·148, 83·320
4	613	81·873	80·157, 83·609	665	81·228	79·705, 82·767	675	81·067	79·757, 82·388	611	80·565	79·018, 82·129
≥5	242	81·018	79·270, 82·786	327	81·048	79·347, 82·768	380	80·469	78·750, 82·209	486	78·683	77·244, 80·136
R^2 (adjusted R^2)		0·169	0·156		0·188	0·173		0·212	0·196		0·240	0·224
P value		0·493			0·848			0·009			<0·001	
Snack frequency†												
0	918	81·902	80·103, 83·722	566	80·630	78·881, 82·399	456	83·652	80·766, 86·591	331	82·736	80·326, 85·184
1	757	81·425	79·610, 83·262	775	81·131	79·289, 82·996	745	82·455	79·729, 85·230	651	81·538	79·220, 83·892
2	277	80·929	78·812, 83·076	325	80·901	78·923, 82·906	347	82·485	79·462, 85·569	396	79·531	77·303, 81·792
3	72	81·496	77·807, 85·276	89	80·965	78·391, 83·584	100	80·546	76·672, 84·521	146	80·596	78·068, 83·167
R^2 (adjusted R^2)		0·169	0·154		0·189	0·173		0·213	0·197		0·246	0·229
P value		0·244			0·693			0·022			<0·001	
Meal frequency‡												
1	59	81·456	77·773, 85·230	18	80·238	76·593, 83·974	14	84·664	76·522, 93·247	6	80·806	75·277, 86·546
2	572	81·274	79·552, 83·015	380	81·485	79·804, 83·185	304	81·345	79·828, 82·878	209	82·659	80·844, 84·495
3	1393	81·583	79·959, 83·224	1357	81·000	79·559, 82·454	1330	80·860	79·504, 82·227	1309	79·835	78·502, 81·179
R^2 (adjusted R^2)		0·169	0·154		0·189	0·173		0·213	0·197		0·246	0·229
P value		0·662			0·629			0·232			<0·001	

MAR, mean adequacy ratio.
* Adjusted for age group, sex, smoking status, alcohol drinking frequency, physical activity, resistance exercise frequency, household income, education level, stress level, energy intake:estimated average requirement ratio and depressed mood.
† Adjusted for same variables as in * plus meal frequency.
‡ Adjusted for same variables as in * plus snack frequency.

Table 6. *P* values for pairwise comparisons for body fat percentage (BF%), BMI and waist circumference (WC) according to eating frequency stratified by diet quality index

	3rd quartile of MAR			4th quartile of MAR		
MAR quartiles	BF%	BMI	WC	BF%	BMI	WC
Eating frequency*						
<3 *v.* 3	0·125	0·702	0·159	0·297	0·290	0·249
<3 *v.* 4	0·038	0·196	0·016	0·172	0·071	0·051
<3 *v.* ≥5	0·001	0·068	0·007	0·049	0·005	0·001
3 v. 4	0·450	0·179	0·204	0·537	0·097	0·087
3 *v.* ≥5	0·010	0·061	0·089	0·037	<0·001	<0·001
4 *v.* ≥5	0·027	0·386	0·411	0·066	0·017	0·004
Snack frequency†						
0 *v.* 1			0·058		0·066	0·081
0 *v.* 2			0·166		<0·001	<0·001
0 *v.* 3			0·014		0·051	0·024
1 *v.* 2			0·966		0·025	0·003
1 *v.* 3			0·133		0·416	0·279
2 *v.* 3			0·116		0·386	0·249
Meal frequency‡						
1 *v.* 2						0·535
1 *v.* 3						0·736
2 *v.* 3						<0·001

MAR, mean adequacy ratio.
* Adjusted for age group, sex, smoking status, alcohol drinking frequency, physical activity, resistance exercise frequency, household income, education level, stress level, energy intake:estimated average requirement ratio and depressed mood.
† Adjusted for same variables as in * plus meal frequency.
‡ Adjusted for same variables as in * plus snack frequency.

obesity indicators were significant in the higher two diet quality groups, but not in the lower two diet quality groups.

The pathway between EF and obesity has not yet been fully clarified. However, it had previously been indicated that increased EF is associated with reduced insulin concentration, postprandial lipid levels and lipogenesis[58,59]. Increased EF can decrease the postprandial surge of glucose and thus decrease the amount of insulin released in response[60]. Insulin inhibits lipolysis in adipocytes, primarily through inhibition of lipase enzyme activity, and increases fat deposition[61,62]. Thus, EF may contribute to the development of obesity.

However, despite these theoretical bases, previous clinical studies have shown mixed results. Several studies have revealed the inverse relationship between EF and obesity[61,63]. A study of 499 US adults reported that an EF of four or more was associated with a lower risk of obesity in comparison with an EF of three or fewer[61]. Another study of 330 middle-aged men in France reported a significant inverse relationship between EF and BMI and waist:hip ratio[63]. In contrast, a cross-sectional study of British adults reported a positive association between EF and BMI and between EF and WC[12]. Meanwhile, some clinical trials reported no association between EF and weight loss[64,65], despite key limitations, namely small sample size and an insufficient follow-up time for making substantive conclusions[64,65].

The reason for this inconsistency remains unclear, but the controversy with regard to the association between EF and obesity in previous studies might arise from differences in the diet quality. The type of food eaten along with an increased EF may be important in determining the nature of the relationship between EF and obesity risk. A previous study of Australian adults suggested that higher EF is associated with lower WC and reduced fasting glucose and lipid profile in men, but not in women. They hypothesised that the different results between men and women might be owing to the difference in snacking quality. That is, Australian women who ate more often might eat unhealthy snacks[11]. In our study, diet quality was also a possible effect modifier on the relationship between EF and obesity indicators. Increased EF with low diet quality might countervail the metabolically positive effect of higher EF, and thus not be helpful in reducing obesity. However, previous studies did not consider diet quality, which might play a role in the discrepancy. The mechanism by which diet quality alters the association between EF and obesity has not been sufficiently clarified. However, previous studies suggested that poor diet quality is accompanied by greater insulin resistance and lower adiponectin levels, which is an adipokine that decreases insulin resistance and inflammation[66–68]. This might counterbalance the advantage of high EF on the development of obesity.

The nutrition transition process in Korea has resulted in dietary changes including an increase in the animal food consumption and a decrease in total cereal intake[69]. In this study, we could not find significant differences in EF according to income and education levels. However, the proportions of women were higher in higher-EF groups. A study on Americans also showed no association between diet quality and socioeconomic status[70]. However, the diet quality was improved with income level in adults, and women showed better diet quality. Better diet quality was observed in children and older adults compared with younger and middle-aged adults.

This study has some limitations. First, this is a cross-sectional study, which limited our ability to reveal the causal relationship between EF and obesity. Second, there may be potential recall bias because lifestyle factors, including diet, were based on data retrospectively collected by self-reported questionnaires. Third, dietary variables were estimated by a single 24-h dietary recall instead of three 24-h dietary recalls. This might not reflect the usual diet at the individual level, as day-to-day variation was not considered. Therefore, we only included study subjects who answered that they ate as per usual on the survey day to avoid this bias as much as possible. Finally, the participants of this study were of a single ethnic origin, and thus generalisation of the study results must be undertaken with caution. For all its limitations, the strength of this study is that it is the first to identify the potential effect modification of diet quality on the association between EF and obesity indicators using a representative sample of the Korean population.

In conclusion, we revealed that EF is inversely associated with obesity indicators including BMI, WC and BF%, and the association between EF and these obesity indicators is altered according to diet quality in Korean adults. EF is inversely associated with BMI, WC and BF% when diet quality is high, but not when it is low. Further prospective studies are needed to verify the causal relationship between EF and obesity.

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The authors declare that there are no conflicts of interest.

Supplementary material

For supplementary material/s referred to in this article, please visit https://doi.org/10.1017/S0007114518000557

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