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Diet quality, physical activity, and their association with metabolic syndrome in Korean adults

You Jin Kim Ph.D. [a], Ji-Yun Hwang Ph.D. [b], Hyesook Kim Ph.D. [a], Saejong Park Ph.D. [c,*], Oran Kwon Ph.D. [a,*]

[a] Department of Nutritional Science and Food Management, Ewha Womans University, Seoul, South Korea
[b] Graduate School of Education, Sangmyung University, Seoul, South Korea
[c] Department of Sport Science, Korea Institute of Sport Science, Seoul, South Korea

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ABSTRACT

Objective: The aim of ths study was to investigate the combined association of overall diet quality and physical activity (PA) on the risk for metabolic syndrome (MetS) in Korean adults.
Methods: This cross-sectional study extracted the data on 1008 adults (384 men and 624 women) 20 to 64 y of age. Dietary quality was assessed using a recommended food score (RFS) modified for a Korean diet. The total PA was summed to obtain a metabolic equivalent task score. Participants were classified according to the recommended levels of PA and RFS. Multiple logistic regression analysis was applied to determine the associations of RFS and PA with the prevalence of MetS after adjustment for potential confounders.
Results: About 21% of men and 19% of women were reported to have MetS. Nearly 5% of both sexes reached the recommended level of diet quality and PA. In men, a significantly reduced odds ratio (OR) for MetS (OR, 0.16; 95% confidence interval [CI], 0.09–0.93) and hypertriglyceridemia (OR, 0.25; 95% CI, 0.04–0.99) was found in those with better diet quality, within the strata of high PA. In women, compared with inactive individuals with poor diet quality, the OR for abdominal obesity in those with a better diet quality and who were active was 0.21 (95% CI, 0.05–0.86).
Conclusions: Both diet quality and PA are associated with a lower risk for hypertriglyceridemia in men and abdominal obesity in women. These findings suggest that a sex-specific pattern of association between MetS and lifestyle factors (diet and PA) should be considered in clinical practice.

Introduction

Considering that the prevalence of metabolic syndrome (MetS) increases dramatically with age, identifying and managing its contributing factors early in life are important to alleviate its global health burden [1,2]. Among lifestyle factors, it has been suggested that diet and physical activity (PA) are critical in the prevention and management of MetS [3,4]. Moreover, sex reportedly influences the association of socioeconomic and lifestyle factors to MetS [5,6].

The recommended food score (RFS) is a relatively simple method to assess overall diet quality. Given that food-based dietary quality indices are applied to assess and guide an individual's dietary intake for the promotion of health and prevention of disease, the measurement of overall diet quality can be employed to determine the associations between whole foods and health status [7].

Based on the importance of lifestyle modification in MetS [2], it is possible to suggest that a healthy diet and sufficient PA may have a more favorable effect on individuals with MetS than on inactive individuals who consume a poor quality diet. It has been documented that the dietary intake of a single nutrient and PA were both associated with a lower risk for MetS in the Korean population [1]. Furthermore, PA showed significant interactions with naturally representative dietary patterns in South China, regarding MetS risk [8]. In US adults [9] and adolescents [10], a higher overall healthy eating index and PA level are both associated with a lower risk for MetS. However, the potential combined influence of a relatively simple dietary quality score and PA on MetS risk is not yet fully understood. Therefore, the present study investigated the association of RFS and PA on the risk for MetS and its components in Korean adults.

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* Corresponding author. Tel.: +82 2 3277 6860; Fax: +82 2 3277 6860 (O. Kwon), Tel.: +82 2 970-9562; Fax: +82 2 970 9651 (S. Park)
E-mail address: saejpark@sports.re.kr (S. Park), orank@ewha.ac.kr (O. Kwon).

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Materials and methods

National Fitness Award project

This study was performed within the framework of a cross-sectional study designed to develop criterion-referenced health-related fitness standards for the National Fitness Award project [11]. The National Fitness Award is operated by Korea Sports Promotion Foundation and Ministry of Culture, Sports, and Tourism to promote health by exercise, physical, and sporting activities in daily life. This program started in 2011 and is currently managed by 21 centers. It provides scientific fitness tests, counseling, and exercise prescription. It awards certificates depending on fitness level and improvement.

Participants

We analyzed data from National Fitness Award project 2014–2015 for individuals ≥20 y of age. Of the 3776 individuals, we excluded those <20 or >65 y of age (n = 1541) and those with missing data regarding MetS components (n = 154), PA or RFS (n = 1020), and the covariates (n = 80). Another 53 were excluded because they were receiving treatment for chronic diseases (n = 53). Consequently, 1008 individuals (374 men, 624 women) 20 to 64 y of age were included in the final analysis. This study was approved by the Institutional Review Board (IRB) of Korea Institute of Sport Science and Ewha Womans University.

General characteristics, anthropometrics, and biochemical variables

A structured questionnaire, which included information on demographics, education, smoking, alcohol intake, PA, RFS, and medical history was administered by trained interviewers. Height and weight were measured with a stadiometer (Seca, Seca Corporation, Columbia, MD, USA) and an electronic weight scale (Inbody 720, Biospace, Seoul, Korea), respectively. Waist circumference (WC) was measured at the estimated level of the umbilicus. Body mass index (BMI) was calculated as weight divided by the height squared (kg/m^2). Body fat percentage was evaluated using the Inbody 720 (Biospace, Seoul, Korea) [12]. Systolic and diastolic blood pressure (BP) was measured using automatic sphygmomanometer (HEM-7080IC, Omron, Japan). Blood samples were collected in the morning after a 12-h overnight fast and assayed at the Sure Quest Laboratory (Yongin, South Korea). Total cholesterol (TC), triacylglycerides (TGs), high-density lipoprotein cholesterol (HDL-C), and plasma glucose were analyzed enzymatically, using automated techniques. Plasma low-density lipoprotein cholesterol (LDL-C) concentration was computed by subtracting HDL-C and one-fifth plasma TG from the TC.

Recommended food score

The RFS is a method developed by Kant et al. [13] for evaluating overall diet quality. Kim et al. [7] modified and validated the RFS for the Korean diet. Forty-six foods or food groups, corresponding to recommended food categories, were selected and one response for daily frequency of meals was used to calculate RFS. Participants received 1 point for a recommended food or regular eating pattern if they consumed the food at least once per week. The possible score ranged from 0 to 47 points and items for RFS were assigned points as follows: daily frequency of meals (1), grains (1), legumes (4), vegetables (17), seaweeds (2), fruits (12), fish (5), dairy products (3), nuts (1), and tea (1).

Physcal activity assessment

PA was assessed using the validated Korean version of the International Physical Activity Questionnaire (IPAQ) – short form [14]. Eleven items of PA identified the total minutes in the last 7 d spent on inactivity, walking, and moderate- and vigorous-intensity PA. Responses were converted to metabolic equivalent task hour per week (MET-h/wk): walking = 3.3 METs × d × h; moderate PA = 4 METs × d × h; and vigorous PA = 8 METs × d × h [15]. Total MET scores were created by summing the weekly MET values for the three activity types.

Classification of MetS

Participants were categorized as having MetS by the presence of three or more of the modified National Cholesterol Education Program Adult Treatment Panel III guidelines [16] using the standard WC for Koreans [17]:

- WC ≥90 in men and ≥85 cm in women;
- Plasma TG ≥150 mg/dL;
- Plasma HDL-C <40 in men and <50 mg/dL in women;
- BP ≥130/85 mm Hg; and
- Fasting plasma glucose ≥100 mg/dL.

Table 1
Characteristics of study participants by sex and prevalence of metabolic syndrome*

Variables	Men		*P*-value	Women		*P*-value
	Without MetS	MetS		Without MetS	MetS	
N	304	80		508	116	
Age (y)	37 ± 14.2	46.3 ± 12.9	<0.0001	45.5 ± 12.6	55 ± 9.3	<0.0001
Weight (kg)	72.9 ± 10.8	80.2 ± 11.9	<0.0001	58.3 ± 8.2	64.6 ± 8.6	<0.0001
BMI (kg/m^2)	24.5 ± 3.1	26.8 ± 3.2	<0.0001	23.1 ± 3	26.3 ± 3	<0.0001
Body fat (%)	21.5 ± 6.5	26 ± 5.3	<0.0001	31.1 ± 5.9	36.5 ± 5.3	<0.0001
Lean body mass (kg)	32 ± 4.3	33.3 ± 4.8	0.021	21.5 ± 2.6	22 ± 2.8	0.073
RFS	24 ± 10	25 ± 8.7	0.406	25.4 ± 9.1	27.8 ± 8.7	0.011
Physical activity (METs-h/wk)	17.1 ± 17.1	14.7 ± 15.2	0.256	15.8 ± 16.1	14 ± 14.1	0.260
Family income†			0.994			<0.0001
1st (lowest)	60 (1.97)	16 (20)		137 (27)	53 (46.1)	
2nd	80 (28.6)	24 (30)		100 (19.7)	29 (25.2)	
3rd	97 (31.9)	25 (31.3)		185 (36.4)	24 (20.9)	
4th (highest)	60 (19.7)	15 (18.8)		86 (16.9)	9 (7.8)	
Current smoker‡	80 (26.3)	20 (25)	0.811	4 (0.8)	2 (1.7)	0.310
Current drinker§	227 (74.7)	65 (81.3)	0.220	224 (48)	39 (33.6)	0.005
Marriage‖	147 (48.7)	60 (75)	<0.0001	373 (73.6)	99 (85.3)	0.008
Waist circumference (cm)	84.9 ± 8.1	92.7 ± 7.6	<.0001	80.6 ± 8	89.6 ± 6.6	<0.0001
SBP (mm Hg)	124.5 ± 11.9	133.6 ± 11.4	<0.0001	115.1 ± 12.7	128.1 ± 15.3	<0.0001
DBP(mm Hg)	74.8 ± 10.6	84.4 ± 10.7	<0.0001	71.9 ± 8.5	78.4 ± 11	<0.0001
Total cholesterol (mg/dL)	181.9 ± 37.4	187.6 ± 40.6	<0.0001	191.8 ± 42.9	203.5 ± 36.6	0.007
Triacylglyceride (mg/dL)	101.6 ± 50.3	149.1 ± 52.3	<0.0001	86.5 ± 40.2	134 ± 55.4	<0.0001
HDL-C (mg/dL)	56.8 ± 12.8	47.6 ± 11.1	<0.0001	67.7 ± 14.8	52.6 ± 12.5	<0.0001
LDL-C (mg/dL)	118.9 ± 30.8	121.6 ± 32.4	0.487	119.4 ± 32.5	134.8 ± 33.1	<0.0001
Fasting glucose (mg/dL)	92.7 ± 15	111.2 ± 32.7	<0.0001	92.7 ± 11.3	109.0 ± 22.3	<0.0001

BMI, body mass index; DBP, diastolicblood pressure; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; MET, metabolic equivalent of task; MetS, metabolic syndrome; RFS, recommended food score; SBP, systolic blood pressure

*Data are presented as mean ± SD or frequency (%).

†Family monthly income was categorized into four groups: <$2000; $2000–$3000; $3000–$5000; and >$5,000 (USD).

‡Current smoker was defined as currently smoking or cessation of smoking within the past 12 mo.

§Current drinker was defined as consuming alcohol >1 × /mo.

‖Marriage was defined as reporting married or living as married.

Table 2
Characteristics of study participants by sex and prevalence of the metabolic syndrome

Variables		Men	Women
Abdominal obesity	≥90/85 cm	117 (30.5)*	220 (35.3)
Hypertriglyceridemia	≥150 mg/dL	110 (28.7)	155 (24.8)
Low HDL-C	<40/50 mg/dL	40 (10.4)	107 (17.2)
High blood pressure	≥130/85 mm Hg	180 (46.9)	166 (26.6)
Hyperglycemia	≥100 mg/dL	106 (27.6)	165 (26.4)

HDL-C, high-density lipoprotein cholesterol.
*Number (frequency)

Statistical analyses

All data were statistically analyzed using SAS version 9.4 (SAS Institute, Cary, NC, USA). $P < 0.05$ was considered statistically significant. Participant characteristics were expressed as means and standard deviation (SD) for continuous variables and as number (percentages) for categorical variables. The characteristics of the study population were analyzed by the Student's t test for continuous variables and a χ^2 test for categorical variables. The Cochran-Mantel-Haenszel analysis was used to determine the linear trends across income groups.

Participants were classified by the recommended levels of PA and RFS. Optional cutoff points of RFS (≥37 and <37 score) and PA (≥21 and <21 METs-h/wk) were decided and validated by Kim et al. [7] and Kim and Choi [1], respectively. To evaluate combined associations of RFS and PA on MetS, we categorized a combined categorical variable, as follows:

- Low RFS and low PA (reference; both low),
- Low RFS and high PA (high PA alone),
- High RFS and low PA (high RFS alone), and
- High RFS and high PA (both high).

Multiple logistic regression analysis was applied to estimate the odds ratio (OR) and its corresponding 95% confidence interval (CI) for MetS, by a combined class of RFS and PA. We also tested for an interaction between RFS and PA, and estimated the RFS effect by PA, using multiple logistic regression with adjustment for potential confounders. The variables that showed significantly different means or distributions to the main independent variables (RFS and PA) and outcome variables were considered as potential confounders and adjusted in the analyses. Age was highly correlated with other sociodemographic characteristics, as well as smoking and drinking and, therefore, additional variables were not controlled to avoid overadjustment. All models were adjusted for age and body fat percentage in men and age and BMI in women.

Results

Characteristics of participants are presented by MetS and sex in Table 1. About 21% of men and 19% of women were classified as having MetS. In both groups, those with MetS were older and had higher values for BMI; body fat percentage; WC; systolic and diastolic BP, TC, LDL-C, TG, and fasting glucose; and lower levels of HDL-C than those without MetS. The mean RFS score was significantly higher in individuals with MetS than in those without MetS in women, but not in men. There was no significant difference in PA for either sex. The sex-specific prevalence of the MetS components is shown in Table 2. The most prevalent MetS component in men was a high BP (47%), followed by abdominal obesity (31%) and hypertriglyceridemia (29%), whereas women had a higher prevalence of abdominal obesity (35%) and low HDL-C (17%).

In both groups, 5% were classified as having the recommended RFS and PA and about 65% as having a low RFS and PA (Fig. 1). Tables 3 and 4 present the participant characteristics according to RFS and PA level. Ten percent of men and 12% of women satisfied the optional cutoff points for RFS. For PA levels, 28% of men and 27% of women met the optional cutoff points. RFS was higher in individuals with greater PA, and vice versa. When compared with those reporting lower RFS points, those endorsing an RFS ≥37 points had a significantly higher PA level (15.5 versus 26.4 for men [$P = 0.0001$] and 14.8 versus 20 for women [$P = 0.004$], respectively). Similarly, when RFS points were evaluated by dichotomized PA level, RFS was higher in those with a higher PA level for both men ($P = 0.066$) and women ($P = 0.001$).

Table 5 shows the adjusted associations for the risk for MetS and related components in men and women using a combined categorical variable of RFS and PA. In men, compared with those with a lower RFS within the strata of higher PA, significantly reduced OR for MetS (OR, 0.16; 95% CI, 0.09–0.93) and hypertriglyceridemia

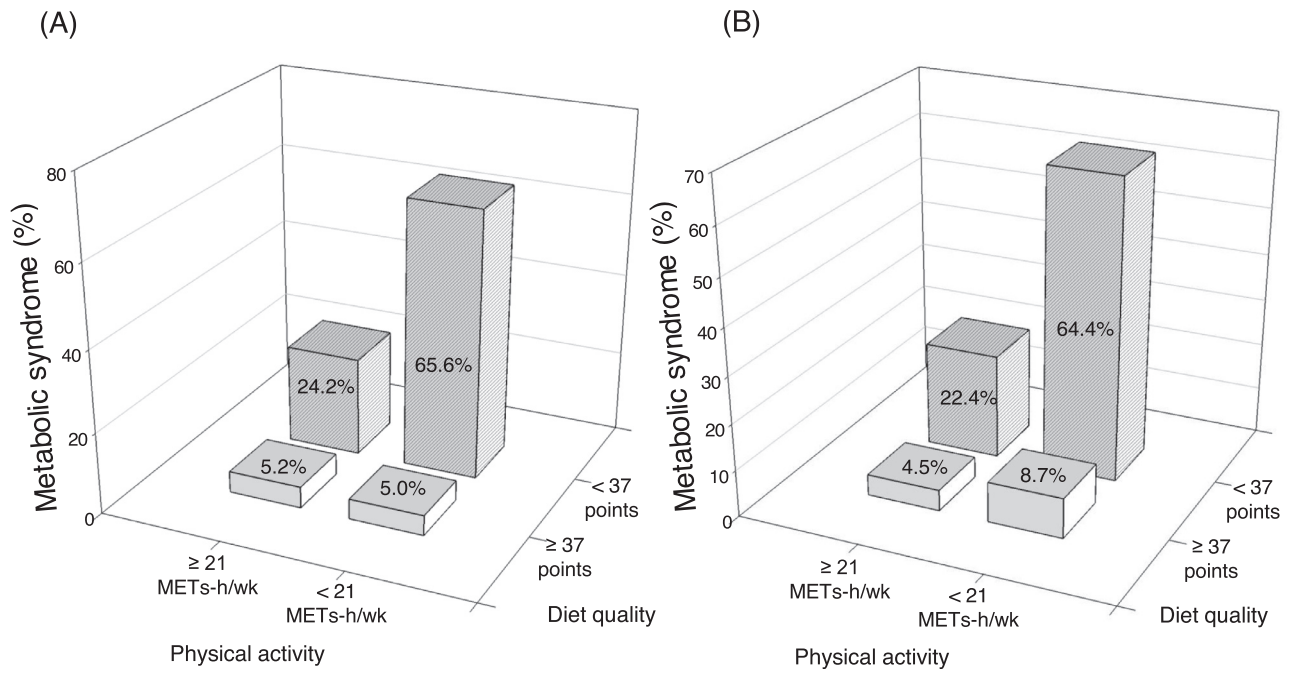

Fig. 1. Joint distributions (percentages) 458 of metabolic syndrome between recommended food score and physical activity in adult (**A**) men and (**B**) women.

Table 3
Selected characteristics of the participants according to recommended food score*

Variables	Men			Women		
	<37 score	≥37 score	*P*-value	<37 score	≥37 score	*P*-value
n	345	39		542	82	
Age (y)	38.3 ± 14.2†	44.9 ± 15.1	0.006	46.5 ± 12.8	52.5 ± 9.5	<0.0001
Weight (kg)	74.6 ± 11.6	72.7 ± 9.2	0.328	59.3 ± 8.5	60.5 ± 9.2	0.218
BMI (kg/m^2)	25 ± 3.4	24.6 ± 1.9	0.454	23.6 ± 3.2	24.1 ± 3.2	0.194
Body fat (%)	22.6 ± 6.6	21.2 ± 4.7	0.204	32 ± 6.2	32.6 ± 5.8	0.433
Lean body mass (kg)	32.3 ± 4.4	32.2 ± 4.4	0.881	21.6 ± 2.7	21.8 ± 2.4	0.431
RFS	22.3 ± 8.4	40.7 ± 3.2	<0.0001	23.6 ± 7.6	40.3 ± 2.4	<00.0001
Physical activity (METs-h/wk)	15.5 ± 15.8	26.4 ± 21.4	0.0001	14.8 ± 15	20 ± 19.6	0.004
Waist circumference (cm)	86.6 ± 8.9	85.2 ± 6.2	0.331	82.1 ± 8.5	83.4 ± 9.1	0.223
SBP (mm Hg)	126.4 ± 12.6	126.3 ± 9.3	0.955	117.1 ± 14.2	120.1 ± 13.2	0.080
DBP (mm Hg)	76.7 ± 11.5	77.3 ± 9.5	0.732	72.9 ± 9.3	74.8 ± 9.4	0.078
Total cholesterol (mg/dL)	182.5 ± 38.8	188.2 ± 30.9	0.272	194.1 ± 42.2	193.3 ± 41.3	0.991
Triacylglyceride (mg/dL)	110.4 ± 54.1	108.5 ± 51.6	0.970	94.8 ± 47.5	97.4 ± 43.9	0.396
HDL-C (mg/dL)	54.6 ± 12.6	57.2 ± 15.8	0.324	65.1 ± 15.5	63.5 ± 15.9	0.331
LDL-C (mg/dL)	119.6 ± 31.4	118.5 ± 28.8	0.951	122.3 ± 33.3	122.1 ± 32.2	0.972
Fasting glucose (mg/dL)	96.6 ± 22.2	96.3 ± 11.3	0.779	95.8 ± 15.9	95.6 ± 11.3	0.846

BMI, body mass index; DBP, diastolic blood pressure; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; MET, metabolic equivalent of task; RFS, recommended food score; SBP, systolic blood pressure
*Data are presented as mean ± SD or frequency (%).
†An optional cutoff value was decided and validated by Kim et al [7].

Table 4
Selected characteristics of the participants according to physical activity*

Variables	Men			Women		
	<21 METs-h/wk†	≥21 METs-h/wk	*P*-value	<21 METs-h/wk	≥21 METs-h/wk	*P*-value
n	271	113		456	168	
Age (y)	39.4 ± 14.5†	38.1 ± 14.2	0.419	17.3 ± 12.6	47.1 ± 12.7	0.812
Weight (kg)	74.1 ± 11.1	75 ± 12.2	0.520	59.3 ± 8.8	59.7 ± 8.0	0.598
BMI(kg/m^2)	25 ± 3.1	25 ± 3.5	0.982	23.6 ± 3.3	23.8 ± 3.1	0.547
Body fat (%)	23.1 ± 6.5	20.9 ± 6.3	0.003	32.2 ± 6.2	31.7 ± 6.1	0.343
Lean body mass (kg)	31.9 ± 4.3	33.2 ± 4.6	0.007	21.5 ± 2.7	21.9 ± 2.5	0.176
RFS	23.6 ± 9.3	25.6 ± 10.5	0.066	25.1 ± 9.1	27.8 ± 8.9	0.001
Physical activity (METs-h/wk)	7.6 ± 5.8	38.3 ± 14.4	<0.0001	7.7 ± 5.7	36.7 ± 14.8	<0.0001
Waist circumference (cm)	87 ± 8.5	85.4 ± 8.8	0.101	82.6 ± 8.6	81.4 ± 8.5	0.118
SBP (mm Hg)	126.2 ± 12.4	126.9 ± 12.2	0.645	117 ± 14.3	119 ± 13.7	0.124
DBP (mm Hg)	77.2 ± 11.5	75.6 ± 10.7	0.204	73.1 ± 9.7	73.1 ± 8.4	0.983
Total cholesterol (mg/dL)	182.5 ± 36.4	184.4 ± 10.7	0.866	192.5 ± 42.2	197.9 ± 41.4	0.139
Triacylglyceride (mg/dL)	110.1 ± 55	110.4 ± 51.1	0.785	98.3 ± 48.7	86.4 ± 40.7	0.003
HDL-C (mg/dL)	53.7 ± 12.4	57.6 ± 14.1	0.008	64.1 ± 15.4	66.9 ± 15.6	0.043
LDL-C (mg/dL)	117.8 ± 30.9	123.6 ± 31.3	0.109	121.6 ± 31.8	124.1 ± 36.5	0.634
Fasting glucose (mg/dL)	97.8 ± 23.5	93.7 ± 14.6	0.083	96.1 ± 14.3	94.9 ± 17.9	0.178

BMI, body mass index; DBP, diastolic blood pressure; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; MET, metabolic equivalent of task; RFS, recommended food score; SBP, systolic blood pressure
*Data are presented as mean ± SD or frequency (%).
†An optional cutoff value was decided and validated by Kim and Choi [1].

(OR, 0.25; 95% CI, 0.04–0.99) was found in those with a higher RFS. There was a significant interaction ($P = 0.037$) between RFS and PA in the probability of having hypertriglyceridemia. RFS, but not PA, was borderline significantly associated with the risk for abdominal obesity ($P = 0.052$). For women, significant ORs for abdominal obesity were observed regardless of the strata of PA (OR, 0.45; 95% CI, 0.23–0.84; OR, 0.16; 95% CI, 0.03–0.72) versus low PA within each RFS strata.

Discussion

The aim of the present study was to examine the sex-specific association of a food-based diet quality score (RFS) and questionnaire-based PA level on the risk for MetS and its related components in Korean adults. Overall, adults with a higher RFS tend to be engaged in more favorable levels of PA, and vice versa. These findings also indicate that ~5% of Korean adults both consume healthy foods and are sufficiently active, emphasizing the importance of developing strategies to promote health-enhancing behaviors. In the present study, the optional cutoff values of RFS (≥37 and <37 points) and PA (≥21 and <21 METs h/wk) may be explained as meeting the dietary guidelines and effective PA level, considering the good quality diet (composed of abundant plant foods with a large potential amount of dietary antioxidants [7]) and daily life activities of ≥1 h/d, respectively [1]. Furthermore, the findings suggest a sex difference in the combined association of RFS and PA on MetS. Specifically, higher PA showed a combined association with RFS on the risk for MetS and hypertriglyceridemia in men. Also, PA, but not RFS, was inversely associated with abdominal obesity in women. These results indicate that a relatively high diet quality, accompanied by moderate PA, may reduce the risk for MetS.

Table 5
Odds ratios and 95% confidence intervals for metabolic syndrome and its components according to the combined associations of recommended food score and physical activity in adults

	Men						Women					
	PA		PA within strata of RFS	*P*-value			PA		PA within strata of RFS	*P*-value		
	<21 METs-h/wk	≥21 METs-h/wk		RFS	PA	RFS* PA	<21 METs-h/wk	≥21 METs-h/wk		RFS	PA	RFS* PA
Metabolic syndrome				0.129	0.431	0.155				0.529	0.227	0.163
RFS <37	1.00 (reference)*	1.48 (0.78, 2.78)	1.48 (0.77, 2.77)				1.00 (reference)	1.07 (0.61, 1.88)	1.07 (0.60, 1.87)			
RFS ≥37	0.93 (2.91, 2.98)	0.24 (0.03, 1.93)	0.26 (0.01, 2.00)				1.33 (0.65, 2.75)	0.50 (0.15, 1.70)	0.38 (0.09, 1.36)			
RFS within strata of PA	0.93 (0.27, 2.85)	0.16 (0.09, 0.93)					1.33 (0.63, 2.71)	0.47 (0.11, 1.54)				
Abdominal obesity				0.052	0.291	0.714				0.547	0.003	0.228
RFS <37	1.00 (reference)	1.52 (0.75, 3.08)	1.52 (0.75, 3.09)				1.00 (reference)	0.45 (0.24, 0.85)	0.45 (0.23, 0.84)			
RFS ≥37	0.25 (0.05, 1.28)	0.59 (0.12, 2.98)	2.35 (0.22, 24.78)				1.29 (0.59, 2.85)	0.21 (0.05, 0.86)	0.16 (0.03, 0.72)			
RFS within strata of PA	0.25 (0.04, 1.08)	0.39 (0.05, 1.79)					1.29 (0.58, 2.85)	0.46 (0.10, 1.91)				
Hypertriglyceridemia				0.389	0.100	0.037				0.135	0.111	0.184
RFS <37	1.00 (reference)	1.23 (0.70, 2.14)	1.23 (0.70, 2.13)				1.00 (reference)	0.92 (0.57, 1.47)	0.92 (0.57, 1.46)			
RFS ≥37	1.77 (0.65, 4.81)	0.31 (0.07, 1.40)	0.17 (0.02, 0.87)				0.94 (0.49, 1.80)	0.35 (0.12, 1.07)	0.37 (0.10, 1.20)			
RFS within strata of PA	1.77 (0.64, 4.84)	0.25 (0.04, 0.99)					0.94 (0.48, 1.78)	0.39 (0.11, 1.12)				
Low HDL cholesterol				0.842	0.198	0.669				0.191	0.495	0.965
RFS <37	1.00 (reference)	0.57 (0.23, 1.43)	0.57 (0.21, 1.35)				1.00 (reference)	0.82 (0.47, 1.42)	0.82 (0.46, 1.40)			
RFS ≥37	1.51 (0.40, 5.66)	0.49 (0.06, 3.88)	0.33 (0.02, 2.90)				1.54 (0.78, 3.05)	1.22 (0.47, 3.22)	0.79 (0.25, 2.35)			
RFS within strata of PA	1.51 (0.33, 5.07)	0.86 (0.04, 5.55)					1.54 (0.76, 2.99)	1.50 (0.49, 4.11)				
High blood pressure				0.431	0.198	0.920				0.254	0.591	0.667
RFS <37	1.00 (reference)	1.54 (0.93, 2.55)	1.54 (0.93, 2.56)				1.00 (reference)	1.31 (0.82, 2.11)	1.31 (0.81, 2.10)			
RFS ≥37	0.73 (0.27, 1.94)	1.20 (0.46, 3.14)	1.65 (0.44, 6.30)				1.56 (0.83, 2.93)	1.60 (0.69, 3.73)	1.03 (0.38, 2.77)			
RFS within strata of PA	0.73 (0.27, 1.95)	0.78 (0.28, 2.17)					1.56 (0.82, 2.92)	1.22 (0.49, 2.99)				
Hyperglycemia				0.922	0.796	0.883				0.199	0.313	0.905
RFS <37	1.00 (reference)	1.18 (0.64, 2.16)	1.18 (0.64, 2.16)				1.00 (reference)	0.71 (0.44, 1.14)	0.71 (0.43, 1.13)			
RFS ≥37	1.02 (0.35, 2.94)	1.07 (0.34, 3.32)	1.05 (0.23, 4.59)				0.65 (0.33, 1.26)	0.49 (0.19, 1.28)	0.76 (0.23, 2.26)			
RFS within strata of PA	1.02 (0.35, 2.94)	0.91 (0.26, 2.93)					0.65 (0.32, 1.24)	0.69 (0.23, 1.84)				

MET, metabolic equivalent of task; PA, physical activity; RFS, recommended food score;
*Poor diet quality and physical inactivity served as the references. A good diet indicates a RFS ≥37 points, and PA indicates a metabolic equivalent ≥21 METs hr/wk. The ORs were estimated by using multiple logistic regression models, adjusted for age and body fat percentage. Interactions between RFS and PA (as a dichotomous variable) were examined in the models with an interaction term (RFS × PA). ORs were also estimated within strata defined by RFS (two groups according to a cutoff score of 37) or PA (two groups according to a cutoff score of 21).

It is well known that adopting a healthy, balanced diet and a physically active lifestyle constitutes an essential component of a successful management program for MetS [18]. Current research provides support for the emerging paradigm that dietary and PA behaviors may be interrelated [2,4,19]. It has been postulated that PA may interact with the dietary pattern via neurocognitive enhancement for executive functions and goal-oriented activities [20]. Therefore, PA may enhance an ability that influences the amount and quality of dietary intake and also suppresses unhealthy impulsive dietary choices. It is also presumed that dietary conduct may affect PA because people who eat a healthy diet may perceive having sufficient energy to perform exercise [9]. However, because of the cross-sectional nature of the study design, the directionality of these behaviors cannot be established. Although dietary practice may be associated with PA, the Korean adults in the present study, were 5% more likely to have good diet quality if they were sufficiently active. Notably, a considerable distribution of the study participants was engaged in none or only one of these behaviors. This finding may have important implications for behavior modification programs when attempting to alter unhealthy habits because changing one action could lead to improvements in another.

To our knowledge, this is the first study to investigate the combined association of overall diet quality and PA on the risk for MetS in Korean adults. Thus, it is challenging to compare these findings with similar work. A previous investigation, however, mentioned that individuals who have a healthy dietary pattern, characterized by high intake of rice and vegetables and moderate intake of animal foods, and who are involved in an active lifestyle might benefit more from the prevention of MetS [8]. In addition, a significant interaction between the above two factors also was found in relation to MetS [8]. Even if an interaction between dietary quality and PA could not be observed, the combined benefits of engaging in sufficient PA and eating a healthy diet were associated with improved health outcomes than diet or exercise alone in U.S. adults [9]. Likewise, a population-based cross-sectional survey (the ATTICA study) carried out in Greece also implied that the adoption of the Mediterranean diet by physically active people might contribute to a reduction in the prevalence of MetS [19]. Our observation was supported by a randomized controlled trial in which a combination of a healthy diet and exercise intervention proved more effective than either approach alone in the resolution of MetS [21]. Furthermore, we found a significant interaction between RFS and PA in the risk for hypertriglyceridemia. A concurrent intervention of diet and aerobic exercise is reportedly effective in improving MetS factors including abdominal fat, blood lipid profile (TG, LDL-C, and TC), and insulin resistance [22]. In addition, a meta-analysis revealed that diet, and particularly a combination of diet and exercise, is superior to an exercise intervention alone for improving TC, LDL-C, and TG in adults [23].

The present study demonstrates a sex difference in the combined association of RFS and PA on the risk for abdominal obesity. Notably, a borderline significant association with RFS is more apparent in men, and the association with PA is more evident in women. It implies that the relatively high RFS did not alter the relation between PA and abdominal obesity in women. It is possible that the lack of correlation between nutritional factors and MetS is due to a modification induced in the dietary habits of the participants, motivated by the MetS risk, but that has not been able to prevent the establishment of MetS [24]. This outcome is supported by the results of another investigation, which showed that a PA effect on abdominal obesity is female specific or female sensitive [25]. Moreover, it was stated that a PA promotion in adults, especially among women, who were found to be less physically active than their male counterparts, may play an important role in reducing MetS risk [25]. Nonetheless, although the effect of RFS on the risk for abdominal obesity was of a lower absolute magnitude than that of PA, the RFS was defined by the endorsement of several general, prudent dietary principles and was assessed via self-report. Because of the self-reporting nature of the questionnaire, participants might have endorsed the adoption of desirable behaviors that were not performed but were recognized as healthy [26].

The limitations of the present study should be considered. First, the causality and long-term implications of lifestyle factors on MetS risk were not determined because of this cross-sectional design. Second, self-reported RFS and PA may have recall bias and may be subjected to measurement errors. Classification biases, such as overreporting, cannot be ruled out, and thus the association between RFS and PA is not fully understood. However, overall dietary patterns embrace a useful approach to examine the effects of the whole diet on human health, providing more information than that attainable with the analysis of single nutrients or foods [7]. A self-reporting questionnaire on PA was validated and can be used appropriately to estimate PA levels in the general population [14]. The third and final limitation was that the relatively small number of total participants may have led to type 2 errors.

Conclusion

The present findings highlight that judicious lifestyle patterns, including a healthy dietary habit and PA, may at least in part contribute to a reduction in the prevalence of MetS. Furthermore, a sex-specific pattern of associations is observed between MetS and lifestyle factors. It has been reviewed that men and women may differentially respond to strategies aimed at reducing the prevalence of MetS, such as lifestyle modification [27]. Thus, attention to sex and sex differences should be a mandatory prerequisite of clinical and epidemiologic research on MetS for a better knowledge and development of health strategies [27]. It is in this context that our findings emphasize the effects of sex-specific tailored lifestyle modifications for ameliorating MetS risk that should include recommendations to promoting PA and appropriate dietary behaviors.

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