Nutrition Research and Practice

Original Research

Check for updates

Inverse association of improved adherence to dietary guidelines with metabolic syndrome: the Seoul Metabolic Syndrome Management program

Dongwoo Ham [1*], YoungYun Cho [2,3*], Mi-Suk Park [4], Yun-Sug Park [4], Sun-Young Kim [4], Hye-Min Seol [4], Yoo Mi Park [5], Sunok Woo [5], Hyojee Joung [1,2§], Do-Sun Lim [4,6§]

[1]Institute of Health and Environment, Seoul National University, Seoul 08826, Korea
[2]Department of Public Health, Graduate School of Public Health, Seoul National University, Seoul 08826, Korea
[3]The Korean Dietetic Association, Seoul 07345, Korea
[4]Metabolic Syndrome Management Center of Seoul Metropolitan Government, Seoul 02751, Korea
[5]Health Care Policy Division, Citizen's Health Bureau, Seoul Metropolitan Government, Seoul 04524, Korea
[6]Department of Cardiology, Cardiovascular Center, Korea University Anam Hospital, Seoul 02841, Korea

OPEN ACCESS

ABSTRACT

BACKGROUND/OBJECTIVES: The Seoul Metabolic Syndrome Management (SMESY) program is a 1-yr lifestyle modification program targeting metabolic syndrome (MetS) in Seoul residents. This study investigated the associations between adherence to dietary guidelines and MetS among the SMESY program participants.

SUBJECTS/METHODS: Data of 54,385 participants aged 20–64 yrs who completed the SMESY program in 2015, had information on adherence to dietary guidelines, and were not medicated for diabetes, hypertension, or dyslipidemia were analyzed. Participants underwent MetS screening and completed a lifestyle questionnaire including adherence to 10 dietary guidelines before and after participation. Participants were classified according to the number of MetS risk factors at baseline (MetS group, ≥ 3; risk group, 1–2; healthy group, none). Adherence to dietary guidelines was determined from the number of "yes" responses regarding the fulfillment of each guideline on ≥ 5 days/week. Multiple logistic regression was used to evaluate associations between newly diagnosed MetS and changes in adherence to dietary guidelines.

RESULTS: In the MetS group, MetS prevalence decreased after the SMESY program (men, −41.9%p; women, −48.7%p), and all risk factors were significantly improved ($P < 0.0001$). All groups exhibited improved adherence to all dietary guidelines after participation ($P < 0.0001$). In the MetS group with positively changed adherence scores, the MetS prevalence decreased by −44.1%p for men and −49.5%p for women, whereas the prevalence in those with negative changes decreased by −38.1%p for men and −48.6%p for women. In the risk group, those with positively changed adherence scores had significantly decreased odds ratios (ORs) for newly diagnosed MetS compared with those with negative changes (OR, 0.70; 95% confidence interval [CI], 0.61–0.80 for men; OR, 0.88; 95% CI, 0.79–0.99 for women).

CONCLUSIONS: The SMESY program may effectively reduce the risk of MetS among adults with risk factors by improving adherence to dietary guidelines.

Keywords: Dietary guidelines; guideline adherence; metabolic syndrome

ORCID iDs

Dongwoo Ham
https://orcid.org/0000-0003-2433-2280
YoungYun Cho
https://orcid.org/0000-0002-9401-1311
Mi-Suk Park
https://orcid.org/0000-0001-5554-7765
Yun-Sug Park
https://orcid.org/0000-0002-1024-8574
Sun-Young Kim
https://orcid.org/0000-0001-8572-4101
Hye-Min Seol
https://orcid.org/0000-0002-6625-5773
Yoo Mi Park
https://orcid.org/0000-0002-5953-0378
Sunok Woo
https://orcid.org/0000-0002-3647-3729
Hyojee Joung
https://orcid.org/0000-0003-1182-7786
Do-Sun Lim
https://orcid.org/0000-0001-5751-5177

Author Contributions

Conceptualization: Ham D, Cho Y, Joung H; Data curation: Park MS, Park YS, Kim SY, Seol HM, Park YM, Woo S, Lim DS; Formal analysis: Ham D, Cho Y; Funding acquisition: Park MS, Park YM, Lim DS; Investigation: Ham D, Cho Y, Joung H; Methodology: Ham D, Cho Y, Joung H; Project administration: Park MS, Park YM, Lim DS; Resources: Park MS, Park YS, Kim SY, Seol HM, Park YM, Woo S, Lim DS; Software: Ham D; Supervision: Joung H, Lim DS; Validation: Joung H; Visualization: Ham D; Writing - original draft: Ham D, Cho Y; Writing - review & editing: Park MS, Park YM, Joung H, Lim DS.

INTRODUCTION

Metabolic syndrome (MetS) is defined as the presence of ≥ 3 metabolic risk factors, including abdominal obesity, high blood pressure, high fasting glucose level, high triglyceride (TG) level, and low high-density lipoprotein cholesterol (HDL-C) level [1,2]. MetS is well known to be associated with risks of major non-communicable diseases (NCDs) such as cardiovascular diseases, the leading cause of deaths worldwide [3,4]. A systematic review reported that approximately 20% of adults in the Asia-Pacific region had MetS [5]. Consistent with that finding, the prevalence of MetS among Koreans who received national health screening has increased steadily and reached 26.0% in 2017 [6]. Accordingly, the rapid and steady increases in NCD-related morbidity and mortality worldwide have led to major concerns regarding the effects of MetS on public health [7].

Extensive investigations of the associations between MetS and dietary factors have indicated that the consumption of whole grains, fruits, vegetables, and dairy products correlated inversely with MetS [8-12], whereas the excessive intake of red or processed meat, saturated fat, and sodium was associated with higher MetS risk [13-15]. A previous study conducted among Korean adults reported that diet quality scores based on the regular intake of recommended food groups such as fruits and vegetables were inversely associated with MetS [16].

Dietary guidelines for the general population, such as Dietary Guidelines for Americans and French National Nutrition and Health Program Guideline, were developed according to the evidence on the relationship between dietary factors and MetS. These guidelines have been introduced to promote healthful dietary behavior and, as a result, decrease the risk of MetS [17,18]. Several subsequent studies have reported an inverse relationship between adherence to dietary guidelines and the risk of MetS [19-24]. According to a previous study conducted in the US, adherence to Dietary Guidelines for Americans showed inverse associations with the prevalence of abdominal obesity and high fasting glucose level [19]. Similarly, improvement in adherence to the French National Nutrition and Health Program Guideline significantly lowered the incidence of MetS [20]. Among Korean adults, those who did not adhere to recommendations on dairy product or fruit intake suggested by the Korean Food Guidance System in Dietary Reference Intakes for Koreans had an increased likelihood of having MetS [21].

The Government of Seoul Metropolitan City (capital of South Korea) designed a lifestyle modification program, the Seoul Metabolic Syndrome Management (SMESY) program, which aimed to target the growing number of residents with MetS and NCDs in 2011. The SMESY program assesses the participants' dietary behaviors based on 10 dietary guidelines recommended by the Dietary Guidelines for Korean Adults. According to a previous analysis of the SMESY program data from 2013, the participants' average adherence scores to the dietary guidelines increased after 12 mon, compared with the baseline [25].

However, no study has investigated the effects of adherence to dietary guidelines on MetS prevalence or the effects of changes in adherence to each dietary guideline on MetS prevention after the SMESY program. Therefore, this study aimed to elucidate the effectiveness of dietary intervention in the context of the SMESY program by investigating the associations between adherence to dietary guidelines and MetS among participants.

SUBJECTS AND METHODS

Data source and study population

The SMESY program is a 1-yr lifestyle modification program that addresses improving behaviors of diet, physical activity, alcohol consumption, and smoking. In 2011, it was implemented at 25 public health centers in Seoul after a pilot study conducted at 15 public health centers in 2010. Any citizen can voluntarily enroll to the program. Public health centers provide health examinations to the participants and classify them into 3 groups according to the number of MetS risk factors: MetS group, ≥ 3; risk group, 1–2; and healthy group, none. These groups are asked to undergo additional health examinations at public health centers at different intervals during a 1-yr follow-up period: MetS group, after 3, 6, 9, and 12 mon; risk group, after 6 and 12 mon; and healthy group, after 12 mon. After each health examination, the participants are also requested to complete a self-reported questionnaire regarding health-related lifestyle behaviors, including adherence to dietary guidelines, smoking, alcohol consumption, and physical activity. After assessing the health status and lifestyles, all participants receive text messages which provide information on how to improve health behaviors (once per week for the MetS group; once per 2 weeks for the risk group; once per month for the healthy group) and are instructed to attend regular lifestyle counseling (once per 3 mon for the MetS group; once per 6 mon for the risk group; at baseline for the healthy group). The text messages contain advice regarding healthy dietary patterns, smoking cessation, drinking alcohol in moderation, and performing regular physical activity. The lifestyle counseling includes 4 sessions about diet, smoking, alcohol consumption, and physical activity, which are organized by health professionals: dietary suggestions by registered dietitians, quitting smoking and drinking alcohol in moderation by doctors or nurses, and an exercise prescription by physical activity specialists. Detailed information about the SMESY program is available elsewhere [25-28].

Data from the SMESY program conducted in 2015 were included in the analyses. Of the 73,061 adults aged 20–64 yrs who completed the SMESY program in 2015, those who used medicines to treat diabetes, hypertension, or dyslipidemia (n = 15,349), or who had missing information on adherence to the dietary guidelines (n = 3,327) were excluded. Finally, the study population included 54,385 participants who had completed all sections of the SMESY program during a 1-yr period.

This study was approved by the Institutional Review Board of Korea University (KU-IRB-17-EX-160-A-1), and all participants provided written informed consent before participation.

Measurement of risk factors for MetS

Participants were asked to fast for 10 h before each health examination. The waist circumference (WC) was obtained using a measuring tape at the midpoint between the iliac crest and the lowest rib. Blood pressure was measured using an automated sphygmomanometer after a 10-min resting period. Fasting blood glucose (FBG) was determined using the glucose oxidase method [26,29]. Blood TG and HDL-C levels were measured using point-of-care testing systems with Lipid Pro, LABGEO PT10, and LDX® (23 public health centers) or venipuncture (2 public health centers) [25].

MetS was defined according to the National Cholesterol Education Program-Adult Treatment Panel III guideline [1,2] and the Korean standards of abdominal obesity presented by the Korean Society of the Study of Obesity [30]. The following criteria were used to identify

MetS risk factors: WC ≥ 90 cm for men and ≥ 85 cm for women (abdominal obesity), systolic blood pressure (SBP) ≥ 130 mmHg or diastolic blood pressure (DBP) ≥ 85 mmHg (high blood pressure), FBG ≥ 100 mg/dL (high fasting glucose level), TG ≥ 150 mg/dL (high TG level), and HDL-C < 40 mg/dL for men and < 50 mg/dL for women (low HDL-C level). MetS was diagnosed when participants had ≥ 3 MetS risk factors.

Adherence to dietary guidelines

A questionnaire regarding adherence to dietary guidelines was developed by modifying the Dietary Guidelines for Korean Adults developed by the Korea Ministry of Health, Welfare and Family Affairs and the Korea Centers for Disease Control and Prevention in 2008 [31]. Among 23 detailed guidelines, 10 guidelines were selected for the questionnaire after excluding those which were related to alcohol consumption, physical activity, and food hygiene. The questionnaire that focused on adherence to the following guidelines was provided to participants who visited public health centers for health examinations: 1) I eat various kinds of grains and plenty of whole grains; 2) I eat ≥ 2 types of various colored vegetables at every meal; 3) I eat various seasonal fruits every day; 4) I eat dairy products (e.g., milk, yogurt, and cheese) every day; 5) I eat 3 meals a day regularly; 6) I eat a balanced Korean diet based on rice and various side dishes; 7) I avoid salty foods or salty soup; 8) I avoid adding extra table salt or soy sauce to foods; 9) I trim off the fat of meat before eating; and 10) I avoid fried foods. Participants were asked to respond "yes" to each guideline that was fulfilled on ≥ 5 days per week. The adherence score was calculated as the number of guidelines to which the participants provided a "yes" response.

Demographic variables and health-related lifestyle behaviors

Participants were asked to complete the self-reported questionnaires regarding demographic variables and health-related lifestyle behaviors. Information about sex, age group (20–39, 40–59, 60–64 yrs), monthly household income (low, < 2,000,000 Korean won; medium, 2,000,000–3,999,999 Korean won; high, ≥ 4,000,000 Korean won), education level (≤ middle school, high school, ≥ college), marital status (yes, no), and health-related lifestyle behaviors (smoking, alcohol consumption, physical activity) was collected.

Smoking was used to categorize participants into 3 groups: never smokers (never smoked during one's lifetime), past smokers (had smoked previously but not at present), and current smokers (currently smoking at baseline). Alcohol consumption was also used to classify participants into 3 groups according to drinking frequency: non-drinkers (had not consumed alcohol for > 1 yr), moderate drinkers (≤ 2–3 times/mon), and heavy drinkers (≥ 2 times/week). Physical activity level was calculated as the metabolic equivalents (MET)-minutes per week according to the International Physical Activity Questionnaire scoring protocol based on information about the type of physical activity (walking, moderate-intensity activity, vigorous-intensity activity), daily duration (min), and days per week on which each type of physical activity was performed [32,33]. The levels were used to further categorize participants into three groups: inactive (< 600 MET-minutes/week), moderate (600–3,000 MET-minutes/week), and vigorous (> 3,000 MET-minutes/week).

Statistical analysis

All analyses were conducted after stratifying the participants according to the MetS risk status (12,352 people in the MetS group; 32,685 people in the risk group; 9,348 people in the healthy group). Statistical Analysis System software version 9.4 (SAS 9.4, SAS Institute, Cary, NC, USA) was used for all analyses. A 2-sided *P*-value < 0.05 was considered statistically significant.

We calculated the frequencies of each category corresponding to the general characteristics at baseline (e.g., sex, age group, education level, monthly household income, marital status, smoking, alcohol consumption, physical activity) in each group of participants based on the MetS risk status. Mean differences in the levels of MetS risk factors from the baseline to after the SMESY program were compared using a paired t-test, and significant changes in the prevalence of these risk factors were analyzed using McNemar's test. We also calculated the percentages of participants who answered "yes" regarding the fulfillment of each dietary guideline and the total adherence scores before and after the SMESY program. We further classified the participants into 4 subgroups according to the change in adherence to the dietary guidelines: negatively changed, unchanged I (participants with low adherence scores at baseline, 0–5), unchanged II (participants with high adherence scores at baseline, 6–10), and positively changed. A multiple logistic regression was conducted for the risk group and the healthy group to obtain odds ratios (ORs) and 95% confidence intervals (CI) for newly diagnosed MetS according to changes in the adherence to dietary guidelines after adjusting for general characteristics. A statistical model fit of the logistic regression was evaluated by Hosmer and Lemeshow goodness-of-fit statistics [34].

RESULTS

General characteristics of study participants

Table 1 presents the general characteristics of the participants at baseline according to the MetS risk status. The distribution of demographic variables among the participants (age, education level, monthly household income, marital status) and health-related lifestyle behaviors (smoking, alcohol consumption, physical activity) differed significantly according to the MetS risk status (all $P < 0.0001$). The MetS group tended to be older, have lower household incomes, smoke more currently and in the past, drink alcohol more heavily, and perform less physical activity than the risk and the healthy groups.

Changes in MetS risk factors and their prevalence

Table 2 compares the levels and prevalence of participants with MetS risk factors before and after the SMESY program. In the MetS group, the prevalence of MetS decreased by 41.9%p in men and 48.7%p in women, and the prevalence of all MetS risk factors decreased significantly in both sexes (all $P < 0.0001$). Of the 5 MetS risk factors, the greatest decreases in both men and women were observed in the prevalence of low HDL-C level (−26.6%p and −26.9%p, respectively). In the risk group, the prevalence of abdominal obesity (only in women), high blood pressure, high fasting glucose level (only in women), and low HDL-C level decreased after the SMESY program. However, a significant increase in prevalence of high TG level was observed in men. In the healthy group, the prevalence of all MetS risk factors increased after the SMESY program.

Association of changes in adherence to dietary guidelines with MetS

Table 3 presents the changes in adherence to the dietary guidelines from before to after the SMESY program. All 3 groups exhibited significantly improved adherence to all dietary guidelines. Among men and women in the MetS group, those who answered "yes" to "I avoid salty foods or salty soup" (+11.2%p, $P < 0.0001$) and "I eat various seasonal fruits every day" (+7.6%p, $P < 0.0001$) exhibited the greatest improvements respectively relative to the baseline. The average total adherence scores increased significantly in the MetS group (+0.9 for men; +0.6 for women; $P < 0.0001$), which were greater than the changes in the risk group

Table 1. General characteristics of participants at baseline according to the MetS risk status

Variables[1]	MetS group[2]	Risk group[2]	Healthy group[2]	P-value[3]
Sex				< 0.0001
Men	6,412 (51.9)	12,031 (36.8)	2,470 (26.4)	
Women	5,940 (48.1)	20,654 (63.2)	6,878 (73.6)	
Age (yrs)				< 0.0001
20–39	1,812 (14.7)	6,712 (20.5)	2,942 (31.5)	
40–59	7,936 (64.3)	19,350 (59.2)	4,982 (53.3)	
60–64	2,604 (21.1)	6,623 (20.3)	1,424 (15.2)	
Education level				< 0.0001
≤ Middle school	1,543 (13.7)	3,822 (12.8)	834 (9.7)	
High school	3,059 (27.2)	8,687 (29.1)	2,287 (26.6)	
≥ College	6,626 (59.0)	17,355 (58.1)	5,468 (63.7)	
Monthly household income[4]				< 0.0001
Low	1,898 (18.6)	4,935 (18.4)	1,365 (17.9)	
Medium	5,874 (57.5)	15,247 (56.8)	4,195 (54.9)	
High	2,438 (23.9)	6,669 (24.8)	2,075 (27.2)	
Marital status				< 0.0001
Yes	1,862 (15.4)	5,976 (18.7)	2,309 (25.4)	
No	10,250 (84.6)	26,072 (81.4)	6,772 (74.6)	
Smoking				< 0.0001
Never	9,082 (73.5)	26,796 (82.0)	8,309 (88.9)	
Past	1,618 (13.1)	3,119 (9.5)	552 (5.9)	
Current	1,652 (13.4)	2,770 (8.5)	487 (5.2)	
Alcohol consumption[5]				< 0.0001
Non	6,027 (48.8)	16,327 (50.0)	4,680 (50.1)	
Moderate	3,753 (30.4)	11,326 (34.7)	3,609 (38.6)	
Heavy	2,572 (20.8)	5,032 (15.4)	1,059 (11.3)	
Physical activity[6]				< 0.0001
Inactive	7,146 (57.9)	17,200 (52.6)	4,736 (50.7)	
Moderate	4,403 (35.7)	12,952 (39.6)	3,837 (41.1)	
Vigorous	803 (6.5)	2,533 (7.8)	775 (8.3)	

Data shown are number (%) not otherwise specified.
MetS, metabolic syndrome; MET, metabolic equivalents.
[1]The number of missing values were 4,704 for education level, 9,689 for monthly household income, and 1,144 for marital status, respectively.
[2]Participants were classified according to the number of MetS risk factors: MetS group, ≥ 3; risk group, 1–2; healthy group, none.
[3]P-values were obtained from a χ^2 test.
[4]Low: < 2,000,000 Korean won/mon; medium: 2,000,000–3,999,999 Korean won/mon; high: ≥ 4,000,000 Korean won/mon.
[5]Non: participants who had not consumed alcohol for > 1 yr; moderate: ≤ 2–3 times/month; heavy: ≥ 2 times/week.
[6]Inactive: < 600 MET-minutes/week; moderate: 600–3,000 MET-minutes/week; vigorous: > 3,000 MET-minutes/week.

and the healthy group (risk group, +0.6 for men and +0.5 for women; healthy group, +0.7 for men and +0.5 for women; all $P < 0.0001$).

Table 4 compares the changes in levels of MetS risk factors and prevalence of participants with MetS risk factors among the MetS group according to the changes in adherence to dietary guidelines. The levels of MetS risk factors showed significant improvements after the SMESY program, regardless of the changes in adherence score to dietary guidelines in both sexes, except the FBG levels of men in the unchanged I subgroup after 1 yr. In the MetS group with positively changed adherence scores, the prevalence of MetS decreased by −44.1%p for men and −49.5%p for women, whereas the prevalence in those with negatively changed adherence scores decreased by −38.1%p for men and −48.6%p for women.

Table 5 presents association of changes in adherence to dietary guidelines with newly diagnosed MetS among the risk and healthy groups. Among men in the risk group, the participants with positive changes in adherence to all dietary guidelines except adherence

Table 2. Changes in levels of MetS risk factors and the prevalence of participants with risk factors according to the MetS risk status

	MetS group[1]			Risk group[1]			Healthy group[1]		
	Pre	Post	P-value[2]	Pre	Post	P-value[2]	Pre	Post	P-value[2]
Men									
MetS risk factors (mean ± SD)									
WC (cm)	91.5 ± 7.2	90.6 ± 7.0	< 0.0001	84.7 ± 6.8	84.9 ± 6.7	0.0012	80.3 ± 6.2	81.2 ± 6.3	< 0.0001
SBP (mmHg)	134.5 ± 13.8	130.8 ± 12.8	< 0.0001	127.0 ± 13.5	125.8 ± 12.4	< 0.0001	116.5 ± 8.9	118.9 ± 11.0	< 0.0001
DBP (mmHg)	85.7 ± 10.3	83.4 ± 9.8	< 0.0001	80.1 ± 10.2	79.8 ± 9.5	< 0.0001	73.2 ± 7.0	75.1 ± 8.0	< 0.0001
FBG (mg/dL)	107.2 ± 23.6	104.5 ± 21.5	< 0.0001	96.7 ± 15.2	97.1 ± 13.7	0.0043	89.7 ± 6.9	94.3 ± 16.0	< 0.0001
TG (mg/dL)	218.8 ± 106.9	190.1 ± 98.6	< 0.0001	131.2 ± 71.2	134.3 ± 71.5	< 0.0001	91.3 ± 27.0	107.6 ± 52.4	< 0.0001
HDL-C (mg/dL)	39.2 ± 10.6	43.4 ± 10.5	< 0.0001	48.1 ± 12.9	49.8 ± 12.2	< 0.0001	53.6 ± 10.4	54.3 ± 11.6	< 0.0001
Number of MetS risk factors (mean ± SD)	3.5 ± 0.6	2.7 ± 1.2	< 0.0001	1.5 ± 0.5	1.4 ± 1.1	0.0008	0.0	0.6 ± 1.0	NA
Prevalence of MetS risk factors (%)									
Abdominal obesity	65.3	55.3	< 0.0001	19.7	20.2	NS	0.0	6.2	NA
High blood pressure	77.5	57.9	< 0.0001	48.2	40.8	< 0.0001	0.0	17.5	NA
High fasting glucose level	63.6	51.1	< 0.0001	28.7	29.3	NS	0.0	17.9	NA
High triglyceride level	78.7	59.3	< 0.0001	27.0	28.5	0.0008	0.0	13.0	NA
Low HDL-C level	62.0	35.4	< 0.0001	24.6	17.9	< 0.0001	0.0	5.5	NA
MetS	100.0	58.1	NA	0.0	16.5	NA	0.0	5.6	NA
Women									
MetS risk factors (mean ± SD)									
WC (cm)	86.3 ± 7.7	85.4 ± 7.6	< 0.0001	79.4 ± 7.5	79.2 ± 7.4	0.0003	74.4 ± 5.9	74.9 ± 6.3	< 0.0001
SBP (mmHg)	128.9 ± 15.4	124.8 ± 14.0	< 0.0001	118.9 ± 14.0	118.1 ± 13.2	< 0.0001	110.7 ± 9.8	112.0 ± 11.1	< 0.0001
DBP (mmHg)	80.9 ± 10.6	78.5 ± 9.6	< 0.0001	75.2 ± 10.1	74.9 ± 9.4	< 0.0001	70.7 ± 7.3	71.7 ± 8.2	< 0.0001
FBG (mg/dL)	104.6 ± 19.1	101.8 ± 17.2	< 0.0001	95.3 ± 12.8	95.5 ± 11.6	NS	88.3 ± 7.6	91.3 ± 8.6	< 0.0001
TG (mg/dL)	189.9 ± 93.1	161.2 ± 77.5	< 0.0001	118.1 ± 58.9	118.6 ± 57.3	NS	86.5 ± 25.3	96.9 ± 41.7	< 0.0001
HDL-C (mg/dL)	43.4 ± 10.7	49.1 ± 11.6	< 0.0001	53.8 ± 13.7	57.3 ± 13.2	< 0.0001	64.8 ± 10.9	65.0 ± 12.3	NS
Number of MetS risk factors (mean ± SD)	3.4 ± 0.6	2.6 ± 1.3	< 0.0001	1.4 ± 0.5	1.3 ± 1.1	< 0.0001	0.0	0.5 ± 0.8	NA
Prevalence of MetS risk factors (%)									
Abdominal obesity	65.0	52.6	< 0.0001	22.2	21.0	< 0.0001	0.0	4.9	NA
High blood pressure	60.2	39.4	< 0.0001	27.9	22.1	< 0.0001	0.0	8.4	NA
High fasting glucose level	62.1	46.2	< 0.0001	28.6	26.7	< 0.0001	0.0	13.5	NA
High triglyceride level	68.9	46.2	< 0.0001	20.1	20.0	NS	0.0	8.2	NA
Low HDL-C level	81.1	54.2	< 0.0001	41.8	27.9	< 0.0001	0.0	7.9	NA
MetS	100.0	51.3	NA	0.0	13.5	NA	0.0	2.6	NA

MetS, metabolic syndrome; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; FBG, fasting blood glucose; TG, triglyceride; HDL-C, high-density lipoprotein cholesterol; NA, not applicable; NS, not significant.
[1]Participants were classified according to the number of MetS risk factors: MetS group, ≥ 3; risk group, 1–2; healthy group, none.
[2]Mean differences between pre- and post-program were tested using a paired t-test, and changes in prevalence of MetS risk factors were tested using a McNemar's test.

to "I avoid adding extra table salt or soy sauce to foods" showed significant decreases in the prevalence of newly diagnosed MetS compared with the participants with negatively changed adherence (range of ORs, 0.67–0.77; all $P < 0.05$). Among women in the risk group, the participants with positive changes in adherence to the dietary guidelines such as "I eat various kinds of grains and plenty of whole grains" (OR, 0.77; 95% CI, 0.62–0.95), "I eat a balanced Korean diet based on rice and various side dishes" (OR, 0.68; 95% CI, 0.57–0.82), and "I trim off the fat of meat before eating" (OR, 0.81; 95% CI, 0.66–0.99) had significantly decreased prevalence of newly diagnosed MetS. Similarly, in both sexes, an improvement in the total adherence score was inversely associated with newly diagnosed MetS (OR, 0.70; 95% CI, 0.61–0.80 for men; OR, 0.88; 95% CI, 0.79–0.99 for women). Moreover, men in the unchanged II subgroup of the risk group showed a decreased prevalence of newly diagnosed MetS (OR, 0.61; 95% CI, 0.53–0.71), whereas those in the unchanged I subgroup did not show significant change. Among women in the healthy group, significant reductions of ORs for newly diagnosed MetS were observed in the unchanged II subgroup for "I eat ≥ 2 types of various colored vegetables at every meal" (OR, 0.59; 95% CI, 0.35–0.99) and unchanged I/II subgroups for "I eat dairy products (e.g., milk, yogurt, and cheese) every day" (OR, 0.43; 95%

Table 3. Changes in adherence to dietary guidelines according to the MetS risk status

	MetS group[1]			Risk group[1]			Healthy group[1]		
	Pre	Post	P-value[2]	Pre	Post	P-value[2]	Pre	Post	P-value[2]
Men									
Adherence to dietary guideline (% yes)									
I eat various kinds of grains and plenty of whole grains.	69.0	74.4	< 0.0001	67.9	73.1	< 0.0001	70.1	76.0	< 0.0001
I eat ≥ 2 types of various colored vegetables at every meal.	66.5	74.4	< 0.0001	67.6	73.9	< 0.0001	70.0	77.6	< 0.0001
I eat various seasonal fruits every day.	56.6	66.3	< 0.0001	59.0	65.9	< 0.0001	62.2	70.9	< 0.0001
I eat dairy products (e.g., milk, yogurt, and cheese) every day.	44.8	53.9	< 0.0001	46.7	52.8	< 0.0001	53.4	61.2	< 0.0001
I eat 3 meals a day regularly.	65.7	71.8	< 0.0001	68.9	72.6	< 0.0001	73.6	77.8	< 0.0001
I eat a balanced Korean diet based on rice and various side dishes.	72.7	79.5	< 0.0001	75.3	80.1	< 0.0001	77.0	82.3	< 0.0001
I avoid salty foods or salty soup.	62.1	73.3	< 0.0001	68.0	74.8	< 0.0001	73.2	80.8	< 0.0001
I avoid adding extra table salt or soy sauce to foods.	75.6	82.9	< 0.0001	79.1	83.6	< 0.0001	81.1	86.8	< 0.0001
I trim off the fat of meat before eating.	50.3	60.9	< 0.0001	54.0	61.9	< 0.0001	57.2	65.4	< 0.0001
I avoid fried foods.	69.5	77.6	< 0.0001	73.0	79.2	< 0.0001	73.5	80.3	< 0.0001
Total adherence score (mean ± SD)	6.3 ± 2.7	7.2 ± 2.6	< 0.0001	6.6 ± 2.6	7.2 ± 2.5	< 0.0001	6.9 ± 2.7	7.6 ± 2.5	< 0.0001
Women									
Adherence to dietary guideline (% yes)									
I eat various kinds of grains and plenty of whole grains.	78.1	81.9	< 0.0001	76.1	79.3	< 0.0001	71.8	76.1	< 0.0001
I eat ≥ 2 types of various colored vegetables at every meal.	67.5	73.6	< 0.0001	64.8	71.4	< 0.0001	61.2	67.9	< 0.0001
I eat various seasonal fruits every day.	67.5	75.1	< 0.0001	68.0	74.1	< 0.0001	66.7	73.2	< 0.0001
I eat dairy products (e.g., milk, yogurt, and cheese) every day.	49.3	55.8	< 0.0001	49.6	56.5	< 0.0001	51.6	58.9	< 0.0001
I eat 3 meals a day regularly.	64.3	70.9	< 0.0001	64.1	69.4	< 0.0001	60.4	66.9	< 0.0001
I eat a balanced Korean diet based on rice and various side dishes.	71.4	77.1	< 0.0001	71.3	77.0	< 0.0001	69.0	74.4	< 0.0001
I avoid salty foods or salty soup.	72.6	79.5	< 0.0001	76.3	80.7	< 0.0001	76.1	80.2	< 0.0001
I avoid adding extra table salt or soy sauce to foods.	80.8	86.3	< 0.0001	82.2	86.5	< 0.0001	83.7	87.3	< 0.0001
I trim off the fat of meat before eating.	74.9	80.4	< 0.0001	75.3	80.0	< 0.0001	72.9	77.0	< 0.0001
I avoid fried foods.	79.1	85.4	< 0.0001	79.9	85.1	< 0.0001	78.2	82.2	< 0.0001
Total adherence score (mean ± SD)	7.1 ± 2.4	7.7 ± 2.2	< 0.0001	7.1 ± 2.3	7.6 ± 2.2	< 0.0001	6.9 ± 2.4	7.4 ± 2.3	< 0.0001

MetS, metabolic syndrome.
[1] Participants were classified according to the number of MetS risk factors: MetS group, ≥ 3; risk group 1–2; healthy group, none.
[2] Changes in adherence to each dietary guideline were tested using a McNemar's test, and changes in total adherence scores were tested using a paired t-test.

CI, 0.22–0.83 for unchanged I; OR, 0.55; 95% CI, 0.33–0.92 for unchanged II). Among the men, the positively changed adherence to "I avoid adding extra table salt or soy sauce to foods" lowered the OR for newly diagnosed MetS (OR, 0.07; 95% CI, 0.01–0.60).

DISCUSSION

This study investigated the associations between adherence to dietary guidelines and MetS among participants in the SMESY program. Adherence to the dietary guidelines was enhanced after the SMESY program in all groups. Furthermore, the participants with positively changed adherence to the dietary guidelines had significant improvements in the levels and the prevalence of MetS risk factors.

In our study, the levels of all MetS risk factors were improved significantly in the MetS group after 12 mon, but improvements in MetS risk factors were observed partially in the risk group. Moreover, the MetS group exhibited the greatest increase in the adherence scores to the dietary guidelines from before to after the program, compared with the risk and healthy groups. These results are consistent with those of previous studies of the SMESY program [25,26]. It is assumed that group differences in the changes of the levels of MetS risk factors and adherence to the dietary guidelines were due to different frequencies of text message provision and lifestyle counseling for the groups. Similarly, according to a study of a 10-week dietary modification program for employees in a Korean company, participants with

Table 4. Changes in levels of MetS risk factors and the prevalence of participants with risk factors according to changes in adherence to dietary guidelines among the MetS group

	Negatively changed			Unchanged I[1]			Unchanged II[1]			Positively changed		
	Pre	Post	P-value[2]	Pre	Post	P-value[2]	Pre	Post	P-value[2]	Pre	Post	P-value[2]
Men												
MetS risk factors (mean ± SD)												
WC (cm)	91.2 ± 7.3	90.5 ± 7.4	< 0.0001	92.8 ± 7.0	91.6 ± 7.0	< 0.0001	90.6 ± 7.0	90.0 ± 6.8	< 0.0001	91.8 ± 7.2	90.7 ± 7.0	< 0.0001
SBP (mmHg)	134.5 ± 14.0	131.6 ± 14.0	< 0.0001	135.8 ± 14.4	132.1 ± 13.7	< 0.0001	134.5 ± 13.7	130.1 ± 12.3	< 0.0001	134.3 ± 13.7	130.5 ± 12.4	< 0.0001
DBP (mmHg)	86.0 ± 10.3	84.6 ± 10.5	< 0.0001	86.7 ± 11.2	84.3 ± 10.2	< 0.0001	85.2 ± 9.6	82.9 ± 9.5	< 0.0001	85.6 ± 10.4	82.9 ± 9.5	< 0.0001
FBG (mg/dL)	106.7 ± 24.7	104.8 ± 22.8	0.0018	106.3 ± 26.0	105.2 ± 29.6	NS	109.4 ± 22.8	106.3 ± 23.6	< 0.0001	106.4 ± 23.1	103.2 ± 17.7	< 0.0001
TG (mg/dL)	215.7 ± 105.4	191.7 ± 103.0	< 0.0001	218.5 ± 105.9	196.6 ± 104.1	< 0.0001	219.1 ± 105.0	187.5 ± 93.3	< 0.0001	220.1 ± 108.8	189.6 ± 98.1	< 0.0001
HDL-C (mg/dL)	38.3 ± 10.8	42.8 ± 11.3	< 0.0001	40.5 ± 11.5	43.5 ± 11.1	< 0.0001	40.1 ± 10.8	43.8 ± 10.1	< 0.0001	39.0 ± 10.2	43.4 ± 10.1	< 0.0001
Number of MetS risk factors (mean ± SD)	3.5 ± 0.6	2.8 ± 1.3	< 0.0001	3.4 ± 0.6	2.8 ± 1.3	< 0.0001	3.5 ± 0.7	2.7 ± 1.2	< 0.0001	3.5 ± 0.6	2.7 ± 1.3	< 0.0001
Prevalence of MetS risk factors (%)												
Abdominal obesity	63.8	53.8	< 0.0001	73.9	61.7	< 0.0001	62.5	54.0	< 0.0001	66.1	55.7	< 0.0001
High blood pressure	78.7	62.3	< 0.0001	79.7	61.3	< 0.0001	78.1	57.5	< 0.0001	76.2	55.4	< 0.0001
High fasting glucose level	61.2	53.0	< 0.0001	59.0	48.2	< 0.0001	70.2	54.9	< 0.0001	62.2	48.7	< 0.0001
High triglyceride level	75.8	57.7	< 0.0001	75.6	58.6	< 0.0001	81.1	60.8	< 0.0001	79.4	59.5	< 0.0001
Low HDL-C level	65.8	40.2	< 0.0001	55.5	35.6	< 0.0001	58.5	32.4	< 0.0001	63.1	34.5	< 0.0001
MetS	100.0	61.9	NA	100.0	59.0	NA	100.0	58.5	NA	100.0	55.9	NA
Women												
MetS risk factors (mean ± SD)												
WC (cm)	86.2 ± 7.8	85.6 ± 7.7	< 0.0001	86.6 ± 8.5	85.8 ± 9.1	0.0114	85.3 ± 7.6	84.6 ± 7.6	< 0.0001	87.0 ± 7.5	85.6 ± 7.4	< 0.0001
SBP (mmHg)	128.3 ± 15.7	123.7 ± 14.0	< 0.0001	129.3 ± 16.1	125.4 ± 14.7	< 0.0001	129.3 ± 15.0	125.5 ± 14.2	< 0.0001	128.9 ± 15.3	124.9 ± 13.7	< 0.0001
DBP (mmHg)	80.7 ± 10.8	78.4 ± 9.8	< 0.0001	82.2 ± 11.3	80.0 ± 10.5	0.0010	80.5 ± 10.1	78.5 ± 9.4	< 0.0001	81.0 ± 10.8	78.5 ± 9.5	< 0.0001
FBG (mg/dL)	104.5 ± 17.8	101.7 ± 14.5	< 0.0001	104.5 ± 17.7	102.2 ± 17.1	0.0495	105.7 ± 20.8	102.9 ± 18.0	< 0.0001	104.1 ± 18.8	101.0 ± 18.0	< 0.0001
TG (mg/dL)	190.6 ± 94.7	160.1 ± 75.9	< 0.0001	194.9 ± 101.4	167.6 ± 88.8	< 0.0001	189.1 ± 93.4	161.1 ± 78.5	< 0.0001	189.5 ± 91.2	161.2 ± 76.5	< 0.0001
HDL-C (mg/dL)	43.1 ± 10.8	49.8 ± 12.0	< 0.0001	43.3 ± 10.6	48.5 ± 11.8	< 0.0001	43.3 ± 11.0	48.5 ± 11.5	< 0.0001	43.5 ± 10.6	49.1 ± 11.3	< 0.0001
Number of MetS risk factors (mean ± SD)	3.4 ± 0.6	2.7 ± 1.3	< 0.0001	3.4 ± 0.6	2.7 ± 1.3	< 0.0001	3.4 ± 0.6	2.5 ± 1.3	< 0.0001	3.4 ± 0.6	2.6 ± 1.3	< 0.0001
Prevalence of MetS risk factors (%)												
Abdominal obesity	63.6	54.1	< 0.0001	66.9	54.7	< 0.0001	59.7	49.0	< 0.0001	68.7	53.7	< 0.0001
High blood pressure	58.3	39.4	< 0.0001	64.7	44.2	< 0.0001	62.4	41.2	< 0.0001	59.5	37.9	< 0.0001
High fasting glucose level	64.5	49.1	< 0.0001	59.1	51.7	0.0168	63.8	47.3	< 0.0001	60.0	43.3	< 0.0001
High triglyceride level	69.1	45.8	< 0.0001	69.5	46.5	< 0.0001	68.2	45.5	< 0.0001	69.3	46.7	< 0.0001
Low HDL-C level	81.0	53.2	< 0.0001	81.8	57.3	< 0.0001	81.0	55.4	< 0.0001	81.2	53.8	< 0.0001
MetS	100.0	51.4	NA	100.0	58.0	NA	100.0	51.5	NA	100.0	50.5	NA

MetS, metabolic syndrome; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; FBG, fasting blood glucose; TG, triglyceride; HDL-C, high-density lipoprotein cholesterol; NA, not applicable; NS, not significant.

[1] Unchanged I: the participants with low adherence scores (0–5) to the dietary guidelines at baseline; Unchanged II: the participants with high adherence scores (6–10) to the dietary guidelines at baseline

[2] Mean differences between pre- and post-program were tested using a paired t-test, and changes in prevalence of MetS risk factors were tested using a McNemar's test.

Table 5. ORs and 95% CIs of newly diagnosed MetS according to changes in adherence to dietary guidelines among the risk and healthy groups

Adherence to dietary guidelines	Risk group[1]					Healthy group[1]				
	Negatively changed	Unchanged I[2]	Unchanged II[2]	Positively changed	$P_{model\ fit}$[3]	Negatively changed	Unchanged I[2]	Unchanged II[2]	Positively changed	$P_{model\ fit}$[3]
Men										
I eat various kinds of grains and plenty of whole grains.					0.0660					0.2070
No. of subjects	1,014	2,217	7,153	1,647		185	408	1,546	331	
Cases	220	381	1,138	242		5	18	18	10	
OR (95% CI)[4]	1.00	0.82 (0.66–1.01)	0.68 (0.57–0.81)	0.70 (0.56–0.88)		1.00	2.11 (0.74–6.02)	1.58 (0.62–4.05)	0.91 (0.27–3.09)	
I eat ≥ 2 types of various colored vegetables at every meal.					0.3740					0.1968
No. of subjects	1,114	2,562	6,473	1,882		173	496	1,441	360	
Cases	243	434	1,034	270		8	17	103	9	
OR (95% CI)	1.00	0.81 (0.67–0.99)	0.68 (0.57–0.81)	0.67 (0.54–0.82)		1.00	0.86 (0.34–2.22)	1.09 (0.48–2.47)	0.47 (0.15–1.45)	
I eat various seasonal fruits every day.					0.0803					0.1069
No. of subjects	1,162	2,636	6,242	1,991		174	509	1,398	389	
Cases	237	441	993	310		6	24	97	10	
OR (95% CI)	1.00	0.80 (0.66–0.97)	0.68 (0.57–0.81)	0.70 (0.57–0.86)		1.00	1.68 (0.61–4.64)	1.18 (0.46–3.03)	0.64 (0.19–2.08)	
I eat dairy products (e.g., milk, yogurt, and cheese) every day.					0.1529					0.0758
No. of subjects	1,286	2,725	6,005	2,015		199	522	1,358	391	
Cases	239	455	975	312		7	20	96	14	
OR (95% CI)	1.00	0.88 (0.73–1.07)	0.77 (0.65–0.91)	0.77 (0.63–0.95)		1.00	1.56 (0.59–4.11)	1.47 (0.62–3.50)	0.82 (0.28–2.40)	
I eat 3 meals a day regularly.					0.1270					0.1815
No. of subjects	1,032	2,825	6,702	1,472		148	574	1,498	250	
Cases	214	462	1,083	222		6	22	99	10	
OR (95% CI)	1.00	0.79 (0.64–0.96)	0.70 (0.58–0.84)	0.73 (0.58–0.92)		1.00	1.05 (0.37–2.96)	1.06 (0.41–2.78)	0.99 (0.31–3.18)	
I eat a balanced Korean diet based on rice and various side dishes.					0.3995					0.1603
No. of subjects	1,018	2,725	6,693	1,595		163	522	1,490	295	
Cases	229	435	1,066	251		8	16	96	17	
OR (95% CI)	1.00	0.75 (0.61–0.92)	0.66 (0.55–0.79)	0.71 (0.57–0.89)		1.00	0.83 (0.30–2.29)	1.06 (0.44–2.55)	1.48 (0.53–4.15)	
I avoid salty foods or salty soup.					0.1134					0.4339
No. of subjects	1,025	2,785	6,380	1,841		148	532	1,454	336	
Cases	226	421	1,033	301		6	20	102	9	
OR (95% CI)[4]	1.00	0.69 (0.57–0.85)	0.69 (0.58–0.82)	0.74 (0.60–0.92)		1.00	0.95 (0.35–2.53)	1.02 (0.42–2.45)	0.50 (0.16–1.62)	
I avoid adding extra table salt or soy sauce to foods.					0.2213					0.2839
No. of subjects	967	2,880	6,682	1,502		146	540	1,499	285	
Cases	210	448	1,071	252		9	23	100	5	
OR (95% CI)	1.00	0.75 (0.61–0.92)	0.71 (0.58–0.85)	0.80 (0.63–1.00)		1.00	0.87 (0.37–2.06)	0.67 (0.30–1.46)	0.07 (0.01–0.60)	
I trim off the fat of meat before eating.					0.2160					0.2166
No. of subjects	1,154	2,702	6,067	2,108		187	523	1,371	389	
Cases	244	439	992	306		6	18	102	11	
OR (95% CI)	1.00	0.82 (0.67–0.99)	0.76 (0.64–0.90)	0.71 (0.57–0.87)		1.00	2.02 (0.65–6.29)	2.41 (0.85–6.82)	1.58 (0.47–5.32)	
I avoid fried foods.					0.7297					0.1772
No. of subjects	947	2,827	6,564	1,693		149	550	1,454	317	
Cases	184	454	1,089	254		9	22	97	9	
OR (95% CI)	1.00	0.85 (0.68–1.05)	0.81 (0.67–0.99)	0.77 (0.61–0.97)		1.00	0.62 (0.26–1.44)	0.55 (0.26–1.18)	0.44 (0.16–1.25)	

Table 5. (Continued) ORs and 95% CIs of newly diagnosed MetS according to changes in adherence to dietary guidelines among the risk and healthy groups

Adherence to dietary guidelines	Risk group[1]					Healthy group[1]				
	Negatively changed	Unchanged I[2]	Unchanged II[2]	Positively changed	$P_{\text{model fit}}$[3]	Negatively changed	Unchanged I[2]	Unchanged II[2]	Positively changed	$P_{\text{model fit}}$[3]
Total adherence score					0.4489					0.2465
No. of subjects	2,858	856	3,213	5,104		454	166	905	945	
Cases	615	133	461	772		23	11	78	25	
OR (95% CI)	1.00	0.81 (0.65–1.02)	0.61 (0.53–0.71)	0.70 (0.61–0.80)		1.00	2.01 (0.88–4.59)	1.13 (0.64–1.99)	0.52 (0.27–1.01)	
Women										
I eat various kinds of grains and plenty of whole grains.					0.0589					0.7748
No. of subjects	1,637	2,644	14,076	2,297		500	1,147	4,444	787	
Cases	253	308	1,949	275		11	21	128	19	
OR (95% CI)	1.00	0.84 (0.69–1.03)	0.85 (0.72–0.99)	0.77 (0.62–0.95)		1.00	1.17 (0.50–2.77)	1.40 (0.67–2.91)	1.46 (0.61–3.50)	
I eat ≥ 2 types of various colored vegetables at every meal.					0.0637					0.5401
No. of subjects	1,984	3,330	11,995	3,345		609	1,362	3,836	1,071	
Cases	305	392	1,642	446		21	26	104	28	
OR (95% CI)	1.00	0.82 (0.68–0.98)	0.85 (0.73–0.98)	0.87 (0.73–1.04)		1.00	0.54 (0.28–1.03)	0.59 (0.35–0.99)	0.70 (0.38–1.31)	
I eat various seasonal fruits every day.					0.1212					0.9098
No. of subjects	1,805	3,434	12,361	3,054		551	1,387	3,939	1,001	
Cases	255	402	1,716	412		19	27	103	30	
OR (95% CI)	1.00	0.91 (0.75–1.10)	0.96 (0.82–1.13)	0.98 (0.81–1.18)		1.00	0.58 (0.30–1.12)	0.59 (0.35–1.02)	0.72 (0.38–1.38)	
I eat dairy products (e.g., milk, yogurt, and cheese) every day.					0.2129					0.1800
No. of subjects	2,192	3,445	11,416	3,601		608	1,395	3,763	1,112	
Cases	347	392	1,526	520		24	24	93	38	
OR (95% CI)	1.00	0.77 (0.64–0.92)	0.83 (0.72–0.95)	0.89 (0.76–1.06)		1.00	0.43 (0.22–0.83)	0.55 (0.33–0.92)	0.85 (0.48–1.52)	
I eat 3 meals a day regularly.					0.3273					0.9554
No. of subjects	1,714	3,592	12,530	2,818		475	1,457	4,025	921	
Cases	274	427	1,711	373		15	32	114	18	
OR (95% CI)	1.00	0.77 (0.64–0.92)	0.78 (0.66–0.90)	0.83 (0.69–1.01)		1.00	0.91 (0.45–1.84)	0.85 (0.46–1.57)	0.57 (0.26–1.28)	
I eat a balanced Korean diet based on rice and various side dishes.					0.1345					0.2996
No. of subjects	1,889	3,405	12,280	3,080		625	1,324	3,934	995	
Cases	343	392	1,663	387		15	26	113	25	
OR (95% CI)	1.00	0.69 (0.58–0.83)	0.72 (0.63–0.84)	0.68 (0.57–0.82)		1.00	0.84 (0.42–1.67)	0.96 (0.54–1.71)	1.00 (0.50–2.01)	
I avoid salty foods or salty soup.					0.0629					0.9949
No. of subjects	1,617	3,671	12,849	2,517		500	1,475	4,120	783	
Cases	272	414	1,757	342		12	27	114	26	
OR (95% CI)	1.00	0.73 (0.60–0.88)	0.82 (0.70–0.96)	0.86 (0.70–1.04)		1.00	0.82 (0.38–1.77)	0.98 (0.50–1.91)	1.55 (0.72–3.31)	
I avoid adding extra table salt or soy sauce to foods.					0.1580					0.9289
No. of subjects	1,466	3,807	13,031	2,350		444	1,531	4,213	690	
Cases	251	412	1,758	364		13	28	112	26	
OR (95% CI)	1.00	0.70 (0.58–0.85)	0.80 (0.68–0.95)	0.99 (0.81–1.21)		1.00	0.74 (0.35–1.59)	0.82 (0.42–1.59)	1.14 (0.52–2.48)	
I trim off the fat of meat before eating.					0.0661					0.6554
No. of subjects	1,471	3,778	12,959	2,446		449	1,496	4,204	729	
Cases	241	432	1,797	315		15	35	116	13	
OR (95% CI)	1.00	0.66 (0.55–0.80)	0.73 (0.62–0.86)	0.81 (0.66–0.99)		1.00	0.90 (0.44–1.83)	0.81 (0.42–1.53)	0.56 (0.23–1.36)	

Table 5. (Continued) ORs and 95% CIs of newly diagnosed MetS according to changes in adherence to dietary guidelines among the risk and healthy groups

Adherence to dietary guidelines	Risk group[1]					Healthy group[1]				
	Negatively changed	Unchanged I[2]	Unchanged II[2]	Positively changed	$P_{model\ fit}$[3]	Negatively changed	Unchanged I[2]	Unchanged II[2]	Positively changed	$P_{model\ fit}$[3]
I avoid fried foods.					0.1602					0.5164
No. of subjects	1,322	3,770	13,160	2,402		446	1,495	4,216	721	
Cases	206	443	1,841	295		12	30	118	19	
OR (95% CI)	1.00	0.75 (0.61–0.92)	0.81 (0.68–0.97)	0.86 (0.70–1.07)		1.00	0.77 (0.37–1.64)	0.76 (0.39–1.48)	0.89 (0.39–2.05)	
Total adherence score					0.3358					0.3948
No. of subjects	4,988	1,060	5,967	8,639		1,519	459	2,086	2,814	
Cases	785	104	730	1,166		44	10	40	85	
OR (95% CI)	1.00	0.78 (0.61–0.99)	0.74 (0.65–0.83)	0.88 (0.79–0.99)		1.00	1.10 (0.53–2.26)	0.51 (0.31–0.82)	0.93 (0.62–1.41)	

MetS, metabolic syndrome; OR, odds ratio; CI, confidence interval.
[1]Participants were classified according to the number of MetS risk factors: risk group, 1–2; healthy group, none.
[2]Unchanged I: the participants whose adherence to each dietary guideline was 'no' or with low adherence score (0–5) at baseline; Unchanged II: the participants whose adherence to each dietary guideline was 'yes' or with high adherence score (6–10) at baseline.
[3]$P_{model\ fit}$ was obtained from Hosmer and Lemeshow goodness-of-fit test.
[4]ORs and 95% CIs were obtained from a multiple logistic regression adjusted for age, education level, monthly household income, marital status, smoking, alcohol consumption, and physical activity.

MetS who were provided 3 sessions of group nutrition education and individual counseling showed improvement in WC, SBP, DBP, and HDL-C levels, whereas others who did not receive education or counseling showed no significant change except in glycated hemoglobin level [35]. In a randomized controlled trial of MetS patients in Italy, the intervention group, who received 1 yr of active counseling regarding health-related lifestyle factors (diet, alcohol consumption, and physical activity) delivered by professionals, exhibited a greater decrease in the prevalence of MetS and significant improvements in dietary behavior, compared with the control group [36]. These results imply that frequent feedback such as through text messages and active counseling for lifestyle modification in the program can effectively motivate participants to improve their health-related lifestyle behaviors.

A previous systematic review of lifestyle modification programs suggested that changes in lipid profiles during a program should be considered together with various long-term lifestyle behaviors such as diet, smoking, alcohol consumption, and physical activity [37]. In our study, we observed post-program decreases in the prevalence of low HDL-C level and high TG level in the MetS group. Several studies have reported changes in lipid profiles from before to after the lifestyle modification programs; however, the results have been inconsistent. Bo *et al.* [36] reported a significant decrease in the TG level but no significant change in the HDL-C level in participants of a lifestyle modification program. In another study, MetS patients who adhered to the American Heart Association (AHA) dietary guidelines for 1 yr also exhibited a significant improvement in TG level after the program compared with the baseline [38]. According to Mensink *et al.* [39], a lifestyle modification program did not contribute to changes in TG and HDL-C levels of Dutch adults. An Australian study conducted by Pettman *et al.* [40] reported that improvements in the HDL-C level was instead greater in the control group than in the intervention group after a 4-mon program. These previous findings demonstrate the need for further investigations about the long-term effectiveness of interventions for blood lipid levels and the possible interactions of various lifestyle factors (smoking, alcohol consumption, and physical activity).

In this study, among participants in the MetS group, adherence to the guideline "I avoid salty foods or salty soup" improved the most after the program in men, and adherence to the guideline "I avoid adding extra table salt or soy sauce to foods" was the highest after

participation in both men and women. Several epidemiological studies have demonstrated that sodium intake was strongly associated with MetS [14,41,42]. Among Koreans, the sodium intake is generally known to exceed the recommendations of the Dietary Reference Intakes for Korean, AHA, and World Health Organization [43]. The 2 previous studies based on the Korea National Health and Nutrition Examination Surveys during 2007–2009 and 2009–2011 found that only 13.9% and 18.5% of Korean adults, respectively, reported a sodium consumption level of < 2,000 mg/day [44,45]. Therefore, the finding that the SMESY program increased awareness about excessive sodium intake is inspiring. Further dietary interventions intended to target MetS should aim to raise awareness about the negative effects of excessive sodium consumption and adopt proper guidelines that encourage a low-sodium diet.

This study found that the prevalence of MetS among the MetS group decreased regardless of the subgroups stratified by the changes in adherence to dietary guidelines. This result implies that participation in the SMESY program effectively contributed to the decrease in MetS prevalence and the improvements in the levels of risk factors. However, the prevalence of MetS in the subgroup with negatively changed adherence decreased less than that in the subgroup with positively changed adherence in both men and women. Moreover, inverse associations between newly diagnosed MetS and improved adherence to dietary guidelines were identified in the risk group. This implies that not only the dietary behaviors at baseline but also changes in dietary behaviors throughout a lifestyle modification program are related to the MetS risk status after the program. Thus, it is necessary to provide continuous dietary management to the participants with negatively changed or unchanged adherence for effective treatment and prevention of MetS.

It was observed that positively changed adherence to the guideline "I eat a balanced Korean diet based on rice and various side dishes" was inversely associated with newly diagnosed MetS in the risk group. The Korean diet has recently received global recognition as a healthy diet. In a randomized feeding study, Schroeder *et al.* [46] reported that when compared with a typical American diet, a Korean diet led to reductions in the levels of total cholesterol, low-density lipoprotein cholesterol, and FBG. In another study, consumption of a traditional Korean diet containing rice and kimchi was associated with a lower risk of MetS, compared with a diet containing meat and alcohol [47]. According to Lee and Cho [48], a higher Korean dietary pattern score was associated with a lower risk of MetS. Our results may strengthen the evidence supporting the positive aspects of the Korean diet and suggest that this dietary pattern could help address the issue of increasing MetS prevalence.

This study had some limitations. First, the population was not randomly sampled; thus, the results might have selection bias. Specifically, people who visited public health centers and enrolled voluntarily in the SMESY program may have been more health-conscious than the general population. Second, the data might have recall bias because the self-reported questionnaires regarding lifestyle behaviors depended on the participants' memories. Third, the questionnaire regarding adherence to dietary guidelines was not validated although the guidelines were based on the Dietary Guidelines for Korean Adults developed by the government. Fourth, a Cox proportional hazards model could not be applied to this study, even though the data had the characteristics of a 1-yr cohort. Because all participants were followed for the same period, we could not verify whether the data satisfied the assumption of proportional hazards. However, we overcame this limitation by using a multiple logistic regression based on the newly diagnosed patients with MetS to obtain adjusted ORs, rather than simply calculating the crude incident rate ratios.

Despite these limitations, this study had strengths as it enabled large-scale data analyses based on a lifestyle modification program conducted by the Seoul Metropolitan Government. Furthermore, the findings of the present study support the need to include appropriate dietary guidelines in community-based lifestyle modification programs as well as to establish a long-term development plan for the SMESY program.

In conclusion, this study found that the participants with positively changed adherence to the dietary guidelines had significant improvements in the levels and the prevalence of MetS risk factors after the SMESY program. The results imply that greater enrollment in the SMESY program and provision of continuous monitoring system would lead to improvements in the overall health statuses of Seoul residents.

REFERENCES

1. Alberti KG, Eckel RH, Grundy SM, Zimmet PZ, Cleeman JI, Donato KA, Fruchart JC, James WP, Loria CM, Smith SC Jr; International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society; International Association for the Study of Obesity. Harmonizing the metabolic syndrome: a joint interim statement of the International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society; and International Association for the Study of Obesity. Circulation 2009;120:1640-5.
   PUBMED | **CROSSREF**

2. Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults. Executive summary of the third report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). JAMA 2001;285:2486-97.
   PUBMED | **CROSSREF**

3. Eddy DM, Schlessinger L, Heikes K. The metabolic syndrome and cardiovascular risk: implications for clinical practice. Int J Obes 2008;32 Suppl 2:S5-10.
   PUBMED | **CROSSREF**

4. World Health Organization. Cardiovascular diseases (CVDs) [Internet]. Geneva: World Health Organization; 2017 [cited 2018 June 30]. Available from: http://www.who.int/en/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds).

5. Ranasinghe P, Mathangasinghe Y, Jayawardena R, Hills AP, Misra A. Prevalence and trends of metabolic syndrome among adults in the Asia-Pacific region: a systematic review. BMC Public Health 2017;17:101.
   PUBMED | **CROSSREF**

6. Korean Statistical Information Service. National Health Examinations Statistics [Internet]. Wonju: National Health Insurance Service; 2019 [cited 2019 August 28]. Available from: http://kosis.kr/index/index.do.

7. O'Neill S, O'Driscoll L. Metabolic syndrome: a closer look at the growing epidemic and its associated pathologies. Obes Rev 2015;16:1-12.
   PUBMED | **CROSSREF**

8. McKeown NM, Meigs JB, Liu S, Wilson PW, Jacques PF. Whole-grain intake is favorably associated with metabolic risk factors for type 2 diabetes and cardiovascular disease in the Framingham Offspring Study. Am J Clin Nutr 2002;76:390-8.
   PUBMED | **CROSSREF**

9. Shin JY, Kim JY, Kang HT, Han KH, Shim JY. Effect of fruits and vegetables on metabolic syndrome: a systematic review and meta-analysis of randomized controlled trials. Int J Food Sci Nutr 2015;66:416-25.
   PUBMED | **CROSSREF**

10. Lee CJ, Joung H. Milk intake is associated with metabolic syndrome -using data from the Korea National Health and Nutrition Examination Survey 2007~2010. Korean J Community Nutr 2012;17:795-804.
    CROSSREF

11. Hong S, Song Y, Lee KH, Lee HS, Lee M, Jee SH, Joung H. A fruit and dairy dietary pattern is associated with a reduced risk of metabolic syndrome. Metabolism 2012;61:883-90.
    PUBMED | **CROSSREF**

12. Jun S, Ha K, Chung S, Joung H. Meat and milk intake in the rice-based Korean diet: impact on cancer and metabolic syndrome. Proc Nutr Soc 2016;75:374-84.
    PUBMED | CROSSREF

13. Kim Y, Je Y. Meat consumption and risk of metabolic syndrome: results from the Korean population and a meta-analysis of observational studies. Nutrients 2018;10:E390.
    PUBMED | CROSSREF

14. Rhee MY, Kim JH, Kim YS, Chung JW, Bae JH, Nah DY, Kim YK, Lee MM, Lim CY, Byun JE, Park HK, Kang BW, Kim JW, Kim SW. High sodium intake in women with metabolic syndrome. Korean Circ J 2014;44:30-6.
    PUBMED | CROSSREF

15. Riccardi G, Giacco R, Rivellese AA. Dietary fat, insulin sensitivity and the metabolic syndrome. Clin Nutr 2004;23:447-56.
    PUBMED | CROSSREF

16. Kim YJ, Hwang JY, Kim H, Park S, Kwon O. Diet quality, physical activity, and their association with metabolic syndrome in Korean adults. Nutrition 2019;59:138-44.
    PUBMED | CROSSREF

17. DeSalvo KB, Olson R, Casavale KO. Dietary Guidelines for Americans. JAMA 2016;315:457-8.
    PUBMED | CROSSREF

18. Hercberg S, Chat-Yung S, Chaulia M. The French National Nutrition and Health Program: 2001-2006-2010. Int J Public Health 2008;53:68-77.
    PUBMED | CROSSREF

19. Fogli-Cawley JJ, Dwyer JT, Saltzman E, McCullough ML, Troy LM, Meigs JB, Jacques PF. The 2005 Dietary Guidelines for Americans and risk of the metabolic syndrome. Am J Clin Nutr 2007;86:1193-201.
    PUBMED | CROSSREF

20. Kesse-Guyot E, Fezeu L, Galan P, Hercberg S, Czernichow S, Castetbon K. Adherence to French nutritional guidelines is associated with lower risk of metabolic syndrome. J Nutr 2011;141:1134-9.
    PUBMED | CROSSREF

21. Jung HJ, Han SN, Song S, Paik HY, Baik HW, Joung H. Association between adherence to the Korean Food Guidance System and the risk of metabolic abnormalities in Koreans. Nutr Res Pract 2011;5:560-8.
    PUBMED | CROSSREF

22. Al Thani M, Al Thani AA, Al-Chetachi W, Al Malki B, Khalifa SA, Bakri AH, Hwalla N, Naja F, Nasreddine L. Adherence to the Qatar dietary guidelines: a cross-sectional study of the gaps, determinants and association with cardiometabolic risk amongst adults. BMC Public Health 2018;18:503.
    PUBMED | CROSSREF

23. Hosseini-Esfahani F, Jessri M, Mirmiran P, Bastan S, Azizi F. Adherence to dietary recommendations and risk of metabolic syndrome: Tehran Lipid and Glucose Study. Metabolism 2010;59:1833-42.
    PUBMED | CROSSREF

24. Lassale C, Galan P, Julia C, Fezeu L, Hercberg S, Kesse-Guyot E. Association between adherence to nutritional guidelines, the metabolic syndrome and adiposity markers in a French adult general population. PLoS One 2013;8:e76349.
    PUBMED | CROSSREF

25. Choo J, Yoon SJ, Ryu H, Park MS, Lee HS, Park YM, Lim DS. The Seoul Metropolitan lifestyle intervention program and metabolic syndrome risk: a retrospective database study. Int J Environ Res Public Health 2016;13:E667.
    PUBMED | CROSSREF

26. Lee YH, Yoon SJ, Kim HS, Oh SW, Ryu HS, Choo JA, Kim SN, Kim YA, Park MS, Park YS, Kim SY, Kwon AR. Design and preliminary results of a metropolitan lifestyle intervention program for people with metabolic syndrome in South Korea. Diabetes Res Clin Pract 2013;101:293-302.
    PUBMED | CROSSREF

27. Metabolic Syndrome Management Center of Seoul Metropolitan Government. The Seoul Metabolic Syndrome Management program [Internet]. Seoul: Metabolic Syndrome Management Center of Seoul Metropolitan Government; 2010 [cited 2018 June 30]. Available from: http://5check.or.kr/eng/eng_main.html.

28. Park MS, Park YS, Kim SY, Park S, Seol HM, Woo S, Cho S, Lim DS. Introduction and effectiveness of the Seoul Metabolic Syndrome Management. Public Health Aff 2017;1:25-39.
    CROSSREF

29. Trinder P. Determination of glucose in blood using glucose oxidase with an alternative oxygen acceptor. Ann Clin Biochem 1969;6:24-7.
    CROSSREF

30. Lee S, Park HS, Kim SM, Kwon HS, Kim DY, Kim DJ, Cho GJ, Han JH, Kim SR, Park CY, Oh SJ, Lee CB, Kim KS, Oh SW, Kim YS, Choi WH, Woo HJ. Cut-off points of waist circumference for defining abdominal obesity in the Korean population. Korean J Obes 2006;15:1-9.

31. Paik HY, Kim CI, Moon HK, Yoon JS, Joung H, Shim JE, Jung HJ. 2008 Dietary Goals and Dietary Guidelines for Korean Adults. Korean J Nutr 2008;41:887-99.

32. Fogelholm M, Malmberg J, Suni J, Santtila M, Kyröläinen H, Mäntysaari M, Oja P. International physical activity questionnaire: validity against fitness. Med Sci Sports Exerc 2006;38:753-60.
    PUBMED | CROSSREF

33. Craig CL, Marshall AL, Sjöström M, Bauman AE, Booth ML, Ainsworth BE, Pratt M, Ekelund U, Yngve A, Sallis JF, Oja P. International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc 2003;35:1381-95.
    PUBMED | CROSSREF

34. Hosmer DW, Lemeshow S. Applied logistic regression. New York (NY): Wiley; 2000.

35. Kim HJ, Choi I, Kim WG, Asano K, Hong J, Cho YM, Yoon J. Effect of a worksite-based dietary intervention program for the management of metabolic syndrome. Korean J Community Nutr 2016;21:237-46.
    CROSSREF

36. Bo S, Ciccone G, Baldi C, Benini L, Dusio F, Forastiere G, Lucia C, Nuti C, Durazzo M, Cassader M, Gentile L, Pagano G. Effectiveness of a lifestyle intervention on metabolic syndrome. A randomized controlled trial. J Gen Intern Med 2007;22:1695-703.
    PUBMED | CROSSREF

37. Aucott L, Gray D, Rothnie H, Thapa M, Waweru C. Effects of lifestyle interventions and long-term weight loss on lipid outcomes - a systematic review. Obes Rev 2011;12:e412-25.
    PUBMED | CROSSREF

38. Ma Y, Olendzki BC, Wang J, Persuitte GM, Li W, Fang H, Merriam PA, Wedick NM, Ockene IS, Culver AL, Schneider KL, Olendzki GF, Carmody J, Ge T, Zhang Z, Pagoto SL. Single-component versus multicomponent dietary goals for the metabolic syndrome: a randomized trial. Ann Intern Med 2015;162:248-57.
    PUBMED | CROSSREF

39. Mensink M, Blaak EE, Corpeleijn E, Saris WH, de Bruin TW, Feskens EJ. Lifestyle intervention according to general recommendations improves glucose tolerance. Obes Res 2003;11:1588-96.
    PUBMED | CROSSREF

40. Pettman TL, Buckley JD, Misan GM, Coates AM, Howe PR. Health benefits of a 4-month group-based diet and lifestyle modification program for individuals with metabolic syndrome. Obes Res Clin Pract 2009;3:221-35.
    PUBMED | CROSSREF

41. Baudrand R, Campino C, Carvajal CA, Olivieri O, Guidi G, Faccini G, Vöhringer PA, Cerda J, Owen G, Kalergis AM, Fardella CE. High sodium intake is associated with increased glucocorticoid production, insulin resistance and metabolic syndrome. Clin Endocrinol (Oxf) 2014;80:677-84.
    PUBMED | CROSSREF

42. Räisänen JP, Silaste ML, Kesäniemi YA, Ukkola O. Increased daily sodium intake is an independent dietary indicator of the metabolic syndrome in middle-aged subjects. Ann Med 2012;44:627-34.
    PUBMED | CROSSREF

43. Oh HY, Kim MK, Lee M, Kim YO. Macronutrient composition and sodium intake of diet are associated with risk of metabolic syndrome and hypertension in Korean women. PLoS One 2013;8:e78088.
    PUBMED | CROSSREF

44. Lee WJ, Kim HC, Oh SM, Choi DP, Cho J, Suh I. Factors associated with a low-sodium diet: the Fourth Korean National Health and Nutrition Examination Survey. Epidemiol Health 2013;35:e2013005.
    PUBMED | CROSSREF

45. Hong JW, Noh JH, Kim DJ. Factors associated with high sodium intake based on estimated 24-hour urinary sodium excretion: the 2009–2011 Korea National Health and Nutrition Examination Survey. Medicine (Baltimore) 2016;95:e2864.
    PUBMED | CROSSREF

46. Schroeder N, Park YH, Kang MS, Kim Y, Ha GK, Kim HR, Yates AA, Caballero B. A randomized trial on the effects of 2010 Dietary Guidelines for Americans and Korean diet patterns on cardiovascular risk factors in overweight and obese adults. J Acad Nutr Diet 2015;115:1083-92.
    PUBMED | CROSSREF

47. Song Y, Joung H. A traditional Korean dietary pattern and metabolic syndrome abnormalities. Nutr Metab Cardiovasc Dis 2012;22:456-62.
    PUBMED | CROSSREF

48. Lee KW, Cho MS. The traditional Korean dietary pattern is associated with decreased risk of metabolic syndrome: findings from the Korean National Health and Nutrition Examination Survey, 1998–2009. J Med Food 2014;17:43-56.
    PUBMED | CROSSREF