Clin Nutr Res. 2019 Jul;8(3):171-183
https://doi.org/10.7762/cnr.2019.8.3.171
pISSN 2287-3732·eISSN 2287-3740

CLINICAL NUTRITION RESEARCH

Original Article

Check for updates

Importance of Adherence to Personalized Diet Intervention in Obesity Related Metabolic Improvement in Overweight and Obese Korean Adults

OPEN ACCESS

Juhyun An [1] **So Ra Yoon** [1,2,3] **Jae Hyang Lee** [4] **Hyunyoung Kim** [1,2] **Oh Yoen Kim** [1,2]

[1]Department of Food Science and Nutrition, Dong-A University, Busan 49315, Korea
[2]Center for Silver-targeted Biomaterials, Brain Busan 21 Plus Program, Dong-A University, Busan 49315, Korea
[3]Institute of Health Insurance and Clinical Research, National Health Insurance Service Ilsan Hospital, Goyang 10444, Korea
[4]Busan Cardiocerebrovascular Center, Dong-A University Hospital, College of Medicine, Busan 49201, Korea

Received: Jul 7, 2019
Revised: Jul 17, 2019
Accepted: Jul 18, 2019

Correspondence to
Oh Yoen Kim
Department of Food Sciences and Nutrition, Dong-A University, 37 Nakdong-daero 550beon-gil, Saha-gu, Busan 49315, Korea.
E-mail: oykim@dau.ac.kr

ORCID iDs
Juhyun An
https://orcid.org/0000-0001-6532-2447
So Ra Yoon
https://orcid.org/0000-0003-2277-0594
Jae Hyang Lee
https://orcid.org/0000-0002-9781-5841
Hyunyoung Kim
https://orcid.org/0000-0001-7540-9166
Oh Yoen Kim
https://orcid.org/0000-0001-9262-3309

Funding
This study was supported by the National Research Foundation of Korea Grant funded by the Korean Government (2016R1A2B4013627).

Conflict of Interest
The authors declare that they have no competing interests.

ABSTRACT

We investigated weight loss effect of personalized diet education in overweight/obese Korean adults. Overweight/obese Korean adults (body mass index [BMI] ≥ 23 kg/m^2 or waist circumference [WC] ≥ 90 cm for men, ≥ 85 cm for women) were recruited, and 40 participants who completed the 10-week intervention were finally included in the analyses. At first visit, study participants (small group with individual counseling) were educated for optimal diet by clinical dietitian, and checked for their compliance through telephone/text message every 1–2 week during the intervention. Anthropometric and biochemical parameters and dietary intake were investigated. Body weight, BMI, WC, and body fat mass were significantly reduced in whole participants. Hemoglobin A1c, insulin, and low-density lipoprotein cholesterol were also significantly decreased after the intervention. Total energy intake (EI) during the intervention was not significantly decreased compared to the baseline value, but the proportions of energy derived from macronutrients were within the ranges recommended by 2015 Dietary Reference Intake for Koreans. Based on actual EI, participants were classified into high-adherence (HA) (prescribed EI ± 25%, n = 29), low-adherence I (LA-I) (< 75% of prescribed EI, n = 7), and low-adherence II (LA-II) group (> 125% of prescribed EI, n = 4). Only HA group showed significant improvements in anthropometric parameters, glycemic control and lipid profile. Interestingly, LA-I group showed significant increases in glucose, insulin, C-peptide and insulin resistance. In conclusion, a shift from overweight/obesity to healthy weight can be accomplished by high adherence to personalized diet modification, not by EI reduction.

Keywords: Obesity; Diet; Weight; Insulin resistance; Lipid

INTRODUCTION

The prevalence of overweight and obesity has been steadily growing in the earth, which increases the burden of health care costs [1-3]. Korea National Health and Nutrition Survey (KNHNES) reported that 2 in 5 men and 1 in women are obese based on their body mass index (BMI) ≥ 25 kg/m^2 [4]. In addition, the Organization for Economic Cooperation and Development anticipated that obesity rate in Korea will be rapidly increased by 2030 [5]. Excessive fat accumulation is known as a main cause of chronic low-grade inflammation, insulin resistance and dyslipidemia which are associated with risk for type 2 diabetes, cardiovascular disease (CVD) and cancer [3,6-9]. Thus, many endeavors have been tried to prevent and manage obesity [8-13].

Diet therapy is important for weight loss because one of main causes of obesity is the imbalance between energy intake (EI) and expenditure due to unhealthy diet and sedentary lifestyle [11-13]. For example, unhealthy eating habits and dietary attitude can be improved through the nutrition education, thereby changing their practical dietary intake [14-20]. According to Mohammadshahi et al. [19], weekly diet education weekly for 3 months which was conducted to obese women in small group session improved the participants' diet quality scores measured by Healthy Eating Index. In addition, the improved dietary quality might affect the reduction of inflammatory cytokines in the participants independently of the weight loss. In the long-term nutrition education program, the intervention group who had received both individual and group nutritional counseling showed improvement in anthropometric and metabolic parameters, and diet intake compared with control group who did not receive nutritional education [20]. Nutrition education for managing obesity also appears to be effective on the improvement of health parameters [15-20].

Regarding the beneficial effects of diet and nutrition education, the adherence to the intervention is an important factor for the outcomes [11,21-25]. The higher adherence to the lifestyle intervention including more than 80% attendance showed favorable improvements in body weight and cardiometabolic risk factors [26]. A healthy Nordic diet study also reported that the cardiometabolic effect was associated with the adherence to the diet [23]. In addition, Vincent-Baudry et al. [24] confirmed that reduction of CVD risk after 3-month intervention is closely related to the adherence to the dietary recommendations which could be assessed through dietary records and nutritional markers. On the other hand, a randomized intervention trial could not draw any conclusion for the association between the outcome and the adherence for the intervention [25]. Taken together, higher adherence may be a key for the success of nutritional and lifestyle intervention.

However, there are few studies for the association between the adherence to the nutrition education and obesity related metabolic alteration in Korea. Therefore, this study aimed to investigate the weight loss effect of personalized diet education in overweight and obese Korean adults, and to evaluate if the effect is associated with the level of adherence to the education.

MATERIALS AND METHODS

Participants

Overweight and obese Korean adults (BMI ≥ 23 kg/m^2 or waist circumference [WC] ≥ 90 cm for men, ≥ 85 cm for women) were recruited by public advertisement. General characteristics

https://doi.org/10.7762/cnr.2019.8.3.171

including demographic data, medical history, family history, medication intake, physical activity, life and eating habits were obtained from self-reported questionnaire. Participants who have chronic disease (diabetes mellitus, lung disease, CVD, renal failure, cancer, etc.) or attending in weight loss programs or taking medication were excluded. After the screening of 73 individuals who participated in the study, 47 who met the inclusion criteria were involved in the 10-week diet education program. Seven of the participants dropped out for the personal reasons during the intervention. Finally, 40 participants completed the intervention. Participants received the explanation about study aim, procedures and precautions before starting the intervention.

Study design

A personalized dietary intervention study for free-living overweight and obese adults was conducted for 10 weeks. Participants were encouraged to visit 3 times (baseline, 5-week, and 10-week) to complete anthropometric measurements, blood collection and dietary record check. Nutrition education and personalized diet prescription were performed at first-visit. Telephone and text message were provided to each participant by 1- or 2-week intervals during the intervention period to check if they follow the program well. The informed written consent was obtained from all participants.

This study was proceeded after the approval of the Institutional Review Board of Dong-A University (2-1040709-AB-N-01-201310-BR-02-05).

Diet and nutrition education

The education was given by a registered clinical dietitian. The content was developed by the research team with the modification of the guideline from Korean Diabetes Association (KDA) and 2015 Dietary Reference Intakes for Koreans (2015 KDRIs). The recommended proportion of EI derived from macronutrients was as follows: carbohydrates 55%–65%, proteins 7%–20%, fat 15%–30%. The education was conducted to the participants by small group (less than 10 participants) including individual counseling for 1 hour at first-visit. Dietary recommendation was composed of healthy eating habits (what, and how much to eat), some tips when eating-out and cooking for lowering intake of saturated fat and sodium. Food exchange table and food model were used to make participants understood. In the individual counseling, the calorie intake was prescribed to each person for healthy weight based on one's basal metabolic rate and ideal body weight. After then, participants were educated and encouraged to make a meal plan for day for themselves based on the prescribed calorie intake using food exchange table. Expert dietitians also helped them to make a plan and provided tailored feedbacks with their dietary records. Participants were encouraged to contact with the research team when they have questions during the intervention.

Dietary intake assessment

At baseline, 24-hour recall survey and a semi-quantitative food frequency questionnaire with 32 questions based on KNHNES form were conducted. To identify the adherence to the dietary recommendation, 3-day dietary record (2 weekdays and 1 weekend day) was obtained and confirmed by a dietitian at 5-week and 10-week. Computer Aided Nutritional analysis program (CAN-pro 4.0; The Korean Nutrition Society, Seoul, Korea) was used to analyze for dietary energy values and nutrient content from dietary records.

Anthropometric measurements and blood preparation

Height, weight, body fat mass (BFM), skeletal muscle mass (SMM), and visceral fat area (VFA) were measured by automatic body composition analyzer (N20; AIIA Communication Inc., Seongnam, Korea). WC was measured at the midpoint between lower coastal edge and the top of the iliac crest using inextensible tape by the same trained dietitian. Blood pressure was measured in a sitting posture keeping relax by automatic blood pressure monitor (HEM-7220; OMRON, Matsusaka, Japan). Overnight fasting blood was collected at baseline and the end of the study in plain and ethylenediaminetetraacetic acid-treated tubes. Plasma and serum were obtained by centrifugation, aliquoted and frozen at −80°C until analysis.

Lipid profiles and glucose metabolism parameters

Serum concentrations of triglyceride (TG) and total cholesterol (TC) were determined with kits on a Hitachi 7150 autoanalyzer (Hitachi Ltd., Tokyo, Japan). After precipitation of serum chylomicrons with dextran sulfate magnesium, the levels of low-density lipoprotein cholesterol (LDL-C) and high-density lipoprotein cholesterol (HDL-C) in the supernatants were measured enzymatically. Serum fasting glucose levels were analyzed by a glucose oxidase method with a Beckman Glucose Analyzer (Beckman Instruments, Irvine, CA, USA). Hemoglobin A1c (HbA1c) was measured by a glycated hemoglobin analyzer (SD A1cCare™; SD Biosensor Inc., Suwon, Korea). Serum insulin and C-peptide were quantified by radioimmunoassay methods with commercial kits (ImmunoNucleo Corporation, Stillwater, MN, USA). Homeostasis model assessment of insulin resistance (HOMA-IR) was assessed as follows [27]:

$$\text{HOMA-IR} = \text{Fasting Inulin } (\mu\text{IU/mL}) \times \text{Fasting Glucose (mmol/L)}/22.5$$

Statistical analysis

All statistical analyses were done using SPSS version 24.0 for Windows (SPSS Inc., Chicago, IL, USA). To compare the differences in the variables before and after 10-week intervention (within group), paired t-tests were used. Wilcoxon signed-rank sum test was used for the nonparametric test. If variables were skewed distribution, they were tested after log transformed. All results were expressed as mean ± standard error (SE) for continuous variables or number and percentage for categorical variables. Two-sided p value under 0.05 was considered as statistically significant.

RESULTS

General characteristics and anthropometric parameters

General characteristics of study participants during the intervention are presented in **Table 1**. Mean age of participants was 41.0 ± 2.0 years and 60% of them were female. Current smokers and drinkers were 20.0% and 72.5%, respectively. After 10 weeks, body weight, BMI, WC, and BFM were significantly reduced ($p < 0.05$). However, no significant differences were observed in systolic blood pressure and SMM. Diastolic blood pressure was increased (79.9 ± 1.8 vs. 82.4 ± 2.0 mmHg, p = 0.085) and VFA was decreased (110.4 ± 5.0 vs. 105.3 ± 4.9 cm^2, p = 0.279), but they did not reach the statistical significance.

Dietary intake during the intervention

Changes in self-reported dietary intake over 10-week is described in **Table 2**. The EI was not significantly changed compared to the baseline value (1,943.0 ± 97.3 vs. 1,762.3 ± 86.4 kcal/day,

Table 1. General characteristics and anthropometric parameters before and after the intervention

Characteristics	Baseline (n = 40)	5-week (n = 38)	10-week (n = 40)	p_1	p_2
Age (yr)	41.0 ± 2.04				
Female	24 (60)				
Current smokers	8 (20)				
Current drinkers	29 (72.5)				
Regular exercise	15 (37.5)				
Weight (kg)	72.1 ± 1.7	71.1 ± 1.7	71.5 ± 1.8	0.065	0.036
BMI (kg/m²)	26.2 ± 0.4	25.9 ± 0.4	26.0 ± 0.4	0.053	0.027
WC (cm)	90.9 ± 1.1	91.4 ± 1.1	89.5 ± 1.2	0.478	0.007
Systolic blood pressure (mmHg)	125.6 ± 2.8	127.1 ± 2.6	125.8 ± 2.5	0.658	0.926
Diastolic blood pressure (mmHg)	79.9 ± 1.8	83.4 ± 1.9	82.4 ± 2.0	0.032	0.085
VFA (cm²)	110.4 ± 5.0	106.3 ± 4.0	105.3 ± 4.9	0.352	0.279
BFM (kg)	22.5 ± 0.8	22.1 ± 0.9	21.8 ± 0.9	0.353	0.025
SMM (kg)	27.4 ± 1.0	26.4 ± 1.0	27.4 ± 0.9	0.142	0.975

Data presented as means ± SE or number with percentage.; The p value tested by paired t-test; p_1: baseline vs. 5-week, p_2: baseline vs. 10-week; The anthropometric results of 2 participants were not measured at 5-week.
BMI, body mass index; WC, waist circumference; VFA, visceral fat area; BFM, body fat mass; SMM, skeletal muscle mass; SE, standard error.

Table 2. Dietary intake before and after the intervention

Dietary intake	Baseline (n = 40)	5-week (n = 40)	10-week (n = 40)	p_1	p_2
Actual energy intake (kcal/day)	1,943.0 ± 97.3	1,865.8 ± 74.3	1,762.3 ± 86.4	0.462	0.110
Carbohydrate (% kcal/day)	52.0 ± 1.9	59.2 ± 1.1	58.0 ± 1.3	0.001	0.005
Protein (% kcal/day)	18.2 ± 0.9	15.7 ± 0.4	16.0 ± 0.4	0.011	0.032
Fat (% kcal/day)	30.2 ± 1.4	25.1 ± 1.0	26.0 ± 1.1	0.002	0.008
Cholesterol (mg/day)	377.3 ± 33.5	354.2 ± 34.0	329.6 ± 31.5	0.584	0.244
Fiber (g/day)	19.4 ± 1.2	21.1 ± 1.3	17.3 ± 0.9	0.247	0.105

Data presented as means ± SE or number with percent; The p value tested by paired t-test; p_1: baseline vs 5-week, p_2: baseline vs 10-week.
SE, standard error.

p = 0.110). However, after the intervention, the proportions of EI derived from macronutrients were within the ranges suggested by 2015 KDRIs (ratio of carbohydrate:protein:fat = 52:18:30 to 58:16:26, p < 0.05). Total amount of carbohydrate intake (p = 0.477) was not significantly changed, but total amounts of protein and fat intake were significantly decreased compared to the baseline values (protein: −15.9 g/day, p = 0.035; fat: −12.1 g/day, p = 0.031). Precisely, decreased protein intake was mainly due to decreased animal protein intake (−14.1 g/day, p = 0.044). On the other hand, no significant differences before and after the intervention were not observed in vegetable fat intake (−3.6 g/day, p = 0.101) and animal fat intake (−8.5 g/day, p = 0.105). In addition, the ratio of saturated fatty acid to unsaturated fatty acid intake was not significantly changed during the intervention.

Glycemic status and lipid profiles after the intervention

Average values of metabolic parameters at baseline were all in the normal range except that of HbA1c being in the borderline of glucose intolerance (**Table 3**). Fasting glucose was not significantly changed after 10 weeks (98.9 ± 3.9 vs. 95.6 ± 1.8 mg/dL, p = 0.305) but, HbA1c was significantly decreased after the intervention (5.79% ± 0.1% vs. 5.67% ± 0.1%, p = 0.038). Also, fasting insulin was significantly decreased (18.4 ± 3.3 to 10.5 ± 1.1 μIU/mL, p = 0.027) and C-peptide tended to decrease (3.23 ± 0.4 vs. 2.41 ± 0.2 ng/mL, p = 0.052). It may indicate improved insulin sensitivity. Regarding lipid profiles, TG, HDL-C, and TC were not significantly changed, LDL-C was significantly decreased (122.7 ± 5.4 vs. 113.7 ± 4.7 mg/dL, p = 0.047).

https://doi.org/10.7762/cnr.2019.8.3.171

Table 3. Glycemic parameters and lipid profiles before and after the intervention

Parameters	Baseline (n = 40)	10-week (n = 40)	p
Glucose* (mg/dL)	98.9 ± 3.9	95.6 ± 1.8	0.305
HbA1c* (%)	5.79 ± 0.1	5.67 ± 0.1	0.038
Insulin (μIU/mL)	18.4 ± 3.3	10.5 ± 1.1	0.027
C-peptide (ng/mL)	3.23 ± 0.4	2.41 ± 0.2	0.052
HOMA-IR	5.17 ± 1.1	2.48 ± 0.3	0.116
TG* (mg/dL)	119.2 ± 14.6	124.2 ± 14.8	0.576
HDL-C (mg/dL)	57.5 ± 2.1	58.1 ± 2.3	0.594
LDL-C (mg/dL)	122.7 ± 5.4	113.7 ± 4.7	0.047
TC (mg/dL)	196.5 ± 5.7	191.5 ± 4.6	0.226

Data presented as means ± SE; The p value tested by paired t-test.
HbA1c, hemoglobin A1c; HOMA-IR, homeostasis model assessment of insulin resistance; TG, triglyceride; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; SE, standard error.
*Subject tested after log transformed due to the skewed distribution.

General characteristics and dietary intake by the adherence to diet intervention

To examine if the adherence to the diet intervention was associated with obesity related metabolic changes, participants were classified into 3 groups based on actual EI; 1) high-adherence (HA) (prescribed EI ± 25%, n = 29), low-adherence I (LA-I) (< 75% of prescribed EI, n = 7) and low-adherence II (LA-II) group (> 125% of prescribed EI, n = 4). More than 70% of the study participants showed high adherence to the education. After the intervention, HA group presented that proportions of EI derived from macronutrients were significantly shifted into the ranges recommended by 2015 KDRIs. However, it was not observed in the other 2 groups (**Table 4**).

Table 4. General characteristics and dietary intake according to the diet adherence

Characteristics	HA (n = 29)	LA-I (n = 7)	LA-II (n = 4)
Age (yr)	43.6 ± 2.4	33.6 ± 3.2	35.3 ± 6.8
Female	21 (72.4)	1 (14.3)	2 (50.0)
Current smokers	2 (6.9)	5 (71.4)	1 (25.0)
Current drinkers	19 (65.5)	7 (100.0)	3 (75.0)
Basal metabolic rate (kcal/day)	1,391.1 ± 37.3	1,629.4 ± 54.9	1,440.8 ± 121.4
Prescribed energy intake (kcal/day)	1,854.4 ± 53.9	2,224.4 ± 92.0	1,696.0 ± 161.3
Actual energy intake (kcal/day)			
Baseline	1,907.9 ± 115.3	1,928.4 ± 249.1	2,222.8 ± 289.9
5-week	1,836.0 ± 86.3	1,778.8 ± 156.8	2,233.6 ± 275.6
10-week	1,767.9 ± 77.2	1,311.4 ± 156.9*	2,510.2 ± 419.3
Percent carbohydrate (% kcal/day)			
Baseline	52.6 ± 2.4	49.7 ± 3.3	48.2 ± 4.8
5-week	59.7 ± 1.3*	59.6 ± 2.4†	54.7 ± 3.4
10-week	59.1 ± 1.4*	59.4 ± 4.1	48.8 ± 1.8
Percent protein (% kcal/day)			
Baseline	18.4 ± 1.0	18.8 ± 1.6	15.4 ± 2.7
5-week	15.8 ± 0.5*	15.6 ± 0.8	15.2 ± 83.3
10-week	15.9 ± 0.5*	15.1 ± 0.7	18.1 ± 1.5
Percent fat (% kcal/day)			
Baseline	29.0 ± 1.8	31.5 ± 2.0	36.5 ± 3.3
5-week	24.5 ± 1.1*	24.8 ± 2.2	30.1 ± 3.0
10-week	25.0 ± 1.1*	25.4 ± 3.6	33.1 ± 2.1

Data presented as means ± SE; tested by paired t-test or Wilcoxon signed-rank sum test (non-parametric).
HA, high adherence group; LA-I, low adherence I group; LA-II, low adherence II group; SE, standard error.
*$p < 0.05$, †$p < 0.01$ compared with baseline value.

https://doi.org/10.7762/cnr.2019.8.3.171

Anthropometric parameters by the adherence to dietary intervention

After 10 weeks, the HA group showed significant reductions in anthropometric parameters (BMI: 69.4 ± 1.9 vs. 68.8 ± 1.0 kg/m^2, p = 0.031; WC: 89.5 ± 1.3 vs. 87.9 ± 1.3 cm, p = 0.014; VFA: 107.7 ± 6.5 vs. 98.2 ± 5.5 cm^2, p = 0.009; and BFM: 21.9 ± 0.8 vs. 21.0 ± 0.8 kg, p = 0.008) compared to baseline values (**Figure 1**). But these changes were not observed in the LA-I group and LA-II group. In addition, body weight tended to decrease in the HA group (p = 0.050). On the other hand, blood pressures and SMM were not significantly changed in all 3 groups.

Glycemic control and lipid profiles by the adherence to dietary intervention

Changes in glycemic status of the three groups were described in **Figure 2**. HA group showed significant improvements in HbA1c (5.87% ± 0.1% vs. 5.72% ± 0.1%, p = 0.039), insulin (21.1 ± 4.5 vs. 9.12 ± 1.1 μIU/mL, p = 0.012), C-peptide (3.57 ± 0.5 vs. 2.14 ± 0.2 ng/mL, p = 0.009) and HOMA-IR (6.18 ± 1.5 vs. 2.15 ± 0.3, p = 0.026) after the intervention. Glucose level in the HA group tended to decrease (103.5 ± 5.1 vs. 95.7 ± 2.4 mg/dL, p = 0.059). In lipid profile, LDL-C was significantly reduced only in the HA group (125.7 ± 6.4 vs. 113.7 ± 5.9, p = 0.031) as presented in **Figure 3**. On the contrary, LA-I group showed significant increases in the levels of glucose (83.6 ± 3.3 vs. 93.6 ± 1.8, p = 0.028), insulin (8.96 ± 1.7 vs. 13.6 ± 1.7, p = 0.028), C-peptide (2.09 ± 0.3 vs. 3.10 ± 0.4, p = 0.027), and HOMA-IR (1.89 ± 0.4 vs. 3.16 ± 0.4, p = 0.011) after the intervention.

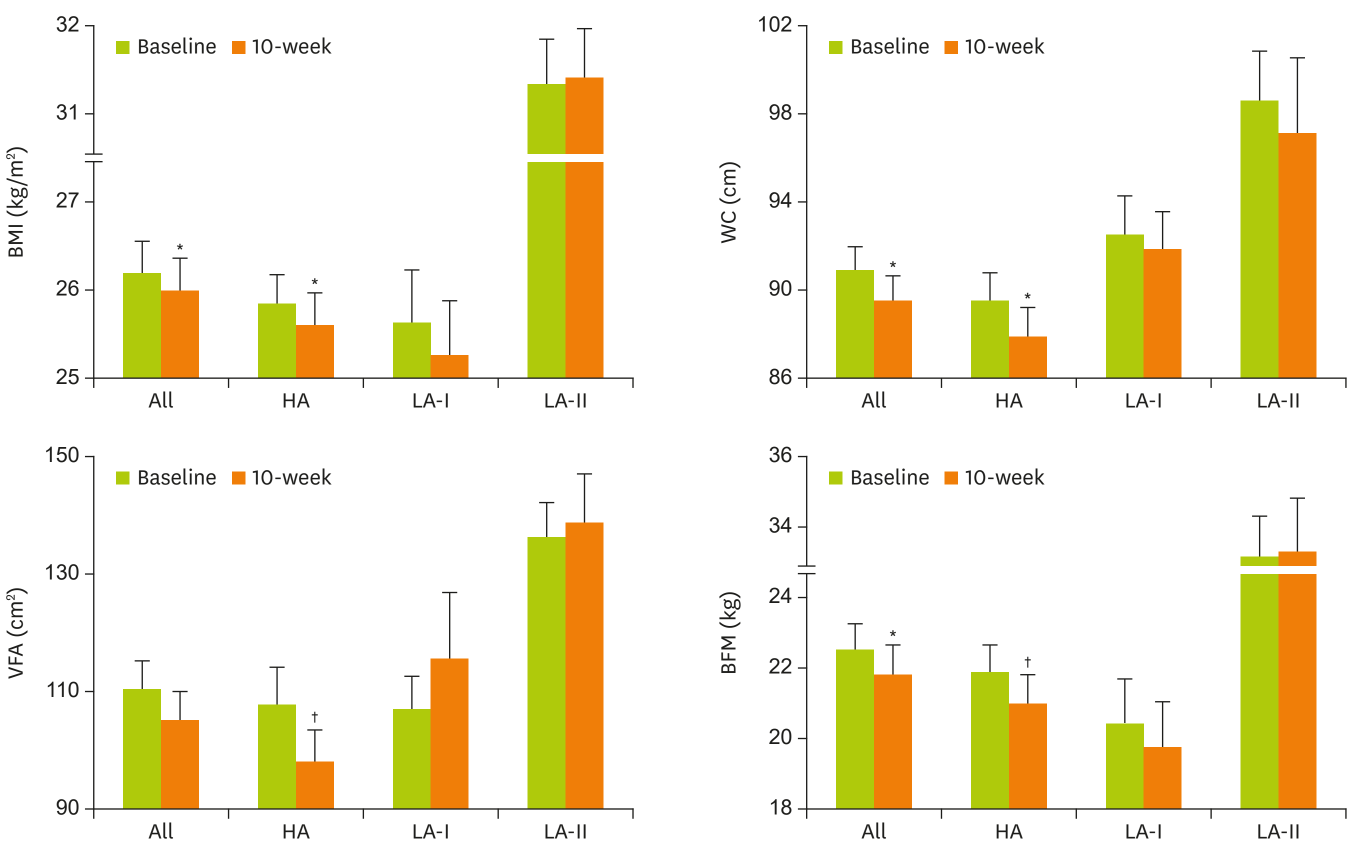

Figure 1. Changes in anthropometric parameters after nutrition education intervention.
Data presented as means ± SE.
BMI, body mass index; WC, waist circumference; VFA, visceral fat area; BFM, body fat mass; HA, high adherence group; LA-I, low adherence I group; LA-II, low adherence II group; SE, standard error.
*Significant difference compared to baseline within group ($p < 0.05$), †significant difference compared to baseline ($p < 0.01$).

https://doi.org/10.7762/cnr.2019.8.3.171

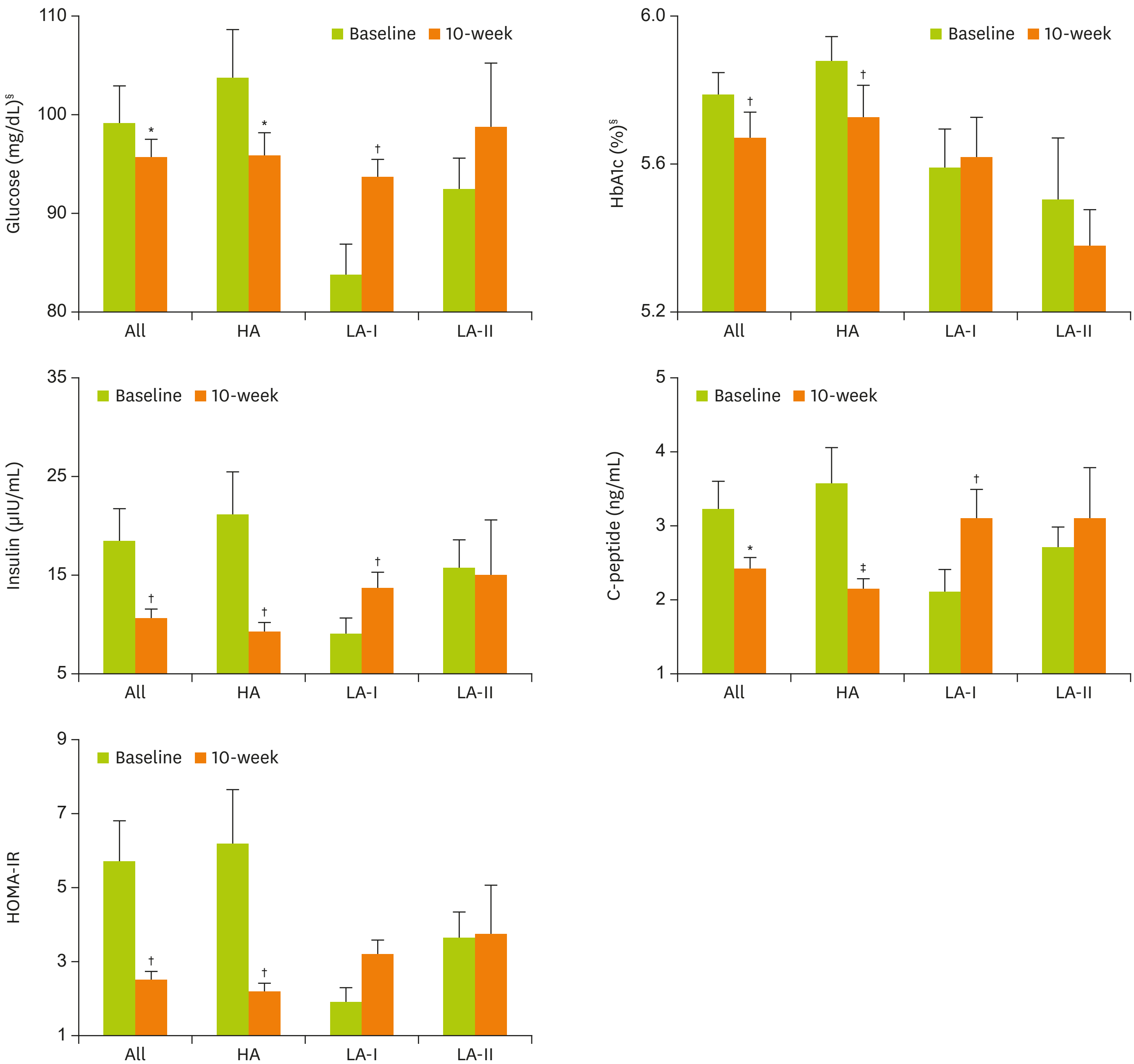

Figure 2. Changes in glycemic status after nutrition education intervention.
Data presented as means ± SE.
HbA1c, hemoglobin A1c; HOMA-IR, homeostasis model assessment of insulin resistance; HA, high adherence group; LA-I, low adherence I group; LA-II, low adherence II group; SE, standard error.
*No significant difference, but trend, $p < 0.1$; †significant difference compared to baseline within group ($p < 0.05$), ‡significant difference compared to baseline ($p < 0.01$); $tested after log transformed due to the skewed distribution.

DISCUSSION

This study was conducted to identify if the weight loss effect of personalized diet education on metabolic changes were associated with the adherence to the intervention. We observed that 73% of participants showed high adherence to the diet education, with resulting in the improvements of anthropometric parameters, glycemic control and lipid profile. These

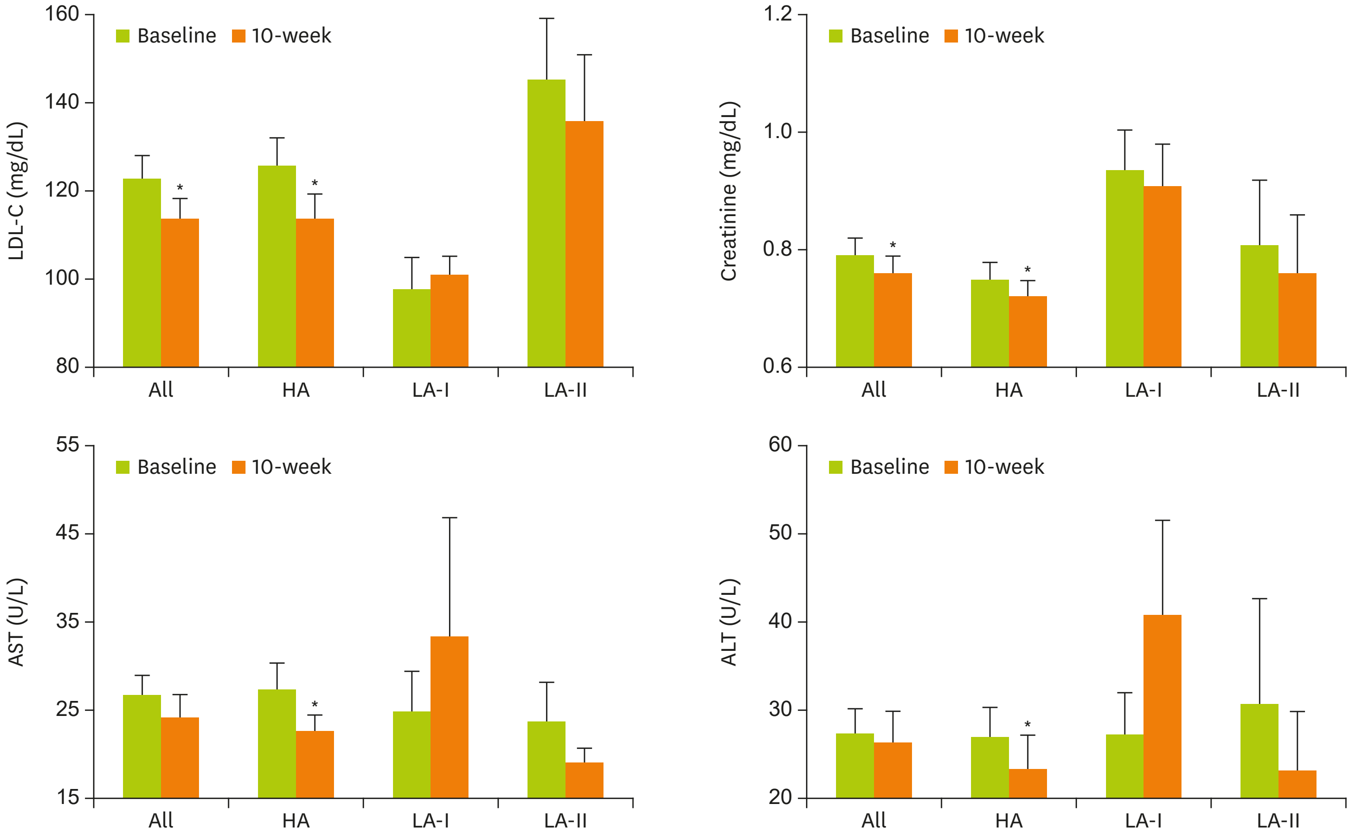

Figure 3. Changes in lipid profile, liver and kidney functions after nutrition education intervention.
Data presented as means ± SE.
LDL-C, low-density lipoprotein cholesterol; AST, aspartate aminotransferase; ALT, alanine aminotransferase; HA, high adherence group; LA-I, low adherence I group; LA-II, low adherence II group; SE, standard error.
*Significant difference compared to baseline within group ($p < 0.05$).

improvements were not observed LA groups. On the contrary, LA-I group who consumed EI < 75% of prescribed EI showed adverse result for glycemic control. It may indicate that higher adherence to dietary recommendation is important to the improvements in metabolic parameters.

Our personalized diet education showed favorable changes in BMI, WC, and BFM in the whole participants during the 10-week intervention by inducing mild EI restriction with following the proportions of macronutrient intake recommended by 2015 KDRIs with dietary pattern modification (i.e. food group selection and nutrient quality beyond EI restriction). It was similar with previous studies showing that personalized nutrition education is effective to reduction in body weight [17,20,22], WC, and BFM [28,29]. Kim et al. [29] reported that people who received additional customized education by telephones during the diet intervention had higher improvement in anthropometric parameters than those with single-visit education, even though there were no significant differences in energy and nutrient intakes between the two groups. In the SYNERGIE intervention study, improved diet quality resulted in the improvements of body composition and fat distribution [28]. It may suggest that diet quality than EI is a stronger contributor to anthropometric improvement [28]. In our study, macronutrient composition in the diet consumed by the HA group was within the range recommended by 2015 KDRIs after the intervention. It may give a beneficial effect on their anthropometric parameters.

https://doi.org/10.7762/cnr.2019.8.3.171

Visceral fat accumulation is a well-known risk factor for CVD [8]. Our study showed that significant decrease in VFA (8.8%), but a decreased tendency of body weight was observed only in the HA group. This finding is consistent with a previous study reporting that high-adherence group for both diet and physical activity showed greater improvement in visceral adipose tissue volume compared with other groups stratified by the levels of adherence [28]. In addition, Arab et al. [30] reported 2% weight loss and 7.4% reduction of VFA after the 8-week lifestyle modification education, and Pinho et al. [31] showed that individualized diet with energy restriction (500–1,000 kcal/day) for 12-week induced 5% weight loss and 11% reduction of VFA in overweight adults [31]. Even though weight loss was relatively smaller in our study than in other studies, comparable reductions of VFA in our study may suggest that big weight loss is not always required to achieve significant VFA reduction.

After the 10-week diet intervention, the HA group showed significant improvements in HbA1c and insulin sensitivity, and decreasing tendency in glucose. On the contrary, the LA-I group showed adverse outcome in glycemic control, that is, the levels of glucose, insulin, C-peptide, and HOMA-IR were significantly increased after the intervention. Considering the cases that EI in the LA-I group was less than basal metabolic rate, we speculated that excessive EI reduction is not suitable for health management in obese people. Also, this result implied that higher adherence to dietary recommendation based on KDA and 2015 KRIs is more effective on glucose control in overweight and obese participants. The finding was in accordance with previous studies showing that HbA1c levels in diabetic patients who received self-management education and individualized nutrition education for 12 weeks were decreased about 0.2% and 0.7%, respectively [16,17]. In addition, a long-term nutrition education program for Brazilian with impaired glucose tolerance showed significant modifications in HbA1c (−1.6%), as well as glucose, insulin and HOMA-IR [20].

A lifestyle modification study by Liu et al. [32] indicated that a clinically significant weight loss of 5% was effective in improving TG, HDL-C, and LDL-C. However, it suggested that improvements in the cardiometabolic risk profile do not always require 5% weight loss in metabolically abnormal obese people [32]. In our study, most participants were in normal range of lipid profiles, and only HA group with mild weight loss showed significant reduction in LDL-C, but not in TG, TC, and HDL-C after the intervention. The Medi-RIVAGE study by Vincent-Baudry et al. [24] showed that reduction in TG, TC, and insulin after the intervention were still maintained with the adjustment for BMI. It may suggest that diet quality is independently beneficial in modulating CVD risk factors [24]. In addition, individualized nutrition education for Koreans with diabetes led to increase intake of mineral and vitamin, thereby resulting in improvement of TG, TC, and LDL-C [17]. Although diet quality could not be calculated in this study, changed nutrient composition in the diet during the intervention might affect metabolic improvement. Therefore, we speculated that dietary habit and food group consumption pattern might affect lipid profile [33].

In our study, 73% of participants showed high adherence to the diet education. Personalized diet education with telephone and text messages might help increase adherence to the diet. Lim et al. [17] have shown that nutrient intakes were improved only in people who received telephone consultation compared to those with non-telephone follow-up. Besides telephone and text messages, new platforms such as internet and mobile device were shown to have beneficial effect on weight control with great potential to overcome resource [34,35]. Younger age and male were suggested as factors associated with poor adherence [36]. It is consistent with the properties shown in the LA group. Psychological factors are also associated with the adherence. Busnello et al. [37] found that previous motivation was associated with the improvement in all clinical parameters after the nutritional intervention. Rodriguez-Cano et al. [38] emphasized to strengthen the motivation to promote healthy food choices and behavioral change. Some literatures reported that nutrition counseling based on the stages of behavioral change was effective in reducing EI for weight loss [39,40].

There were limitations in the present study. First, the number of participants was small and the follow-up duration was relatively short. Therefore, future studies should include more participants and conduct for long-term period including maintenance. In addition, there is a possible bias in dietary survey. Despite the study limitation, we found a shift from overweight and obesity to healthy weight (adequate body fat reduction and metabolic improvement) can be accomplished by high adherence to personalized diet modification, not by EI reduction. Future research should explore the potential factors affecting the deterioration of metabolism in obese people who eat less than dietary recommendations.

REFERENCES

1. World Health Organization. WHO obesity and overweight fact sheet. No. 311. Geneva: World Health Organization; 2016.
2. Hruby A, Hu FB. The epidemiology of obesity: a big picture. Pharmacoeconomics 2015;33:673-89.
PUBMED | CROSSREF
3. Bhupathiraju SN, Hu FB. Epidemiology of obesity and diabetes and their cardiovascular complications. Circ Res 2016;118:1723-35.
PUBMED | CROSSREF
4. Ministry of Health and Welfare, Korea Centers for Disease Control and Prevention. Korea Health Statistics 2017: Korea National Health and Nutrition Examination Survey (KNHANES VII-2). Cheongju: Korea Centers for Disease Control and Prevention; 2018.
5. Organization for Economic Cooperation and Development (OECD). Obesity update 2017. Paris: OECD; 2017.
6. McArdle MA, Finucane OM, Connaughton RM, McMorrow AM, Roche HM. Mechanisms of obesity-induced inflammation and insulin resistance: insights into the emerging role of nutritional strategies. Front Endocrinol (Lausanne) 2013;4:52.
PUBMED | CROSSREF
7. Arnold M, Leitzmann M, Freisling H, Bray F, Romieu I, Renehan A, Soerjomataram I. Obesity and cancer: an update of the global impact. Cancer Epidemiol 2016;41:8-15.
PUBMED | CROSSREF
8. Alegría Ezquerra E, Castellano Vázquez JM, Alegría Barrero A. Obesity, metabolic syndrome and diabetes: cardiovascular implications and therapy. Rev Esp Cardiol 2008;61:752-64.
PUBMED | CROSSREF
9. Meldrum DR, Morris MA, Gambone JC. Obesity pandemic: causes, consequences, and solutions-but do we have the will? Fertil Steril 2017;107:833-9.
PUBMED | CROSSREF
10. Heymsfield SB, Wadden TA. Mechanisms, pathophysiology, and management of obesity. N Engl J Med 2017;376:254-66.
PUBMED | CROSSREF
11. Webb VL, Wadden TA. Intensive lifestyle intervention for obesity: principles, practices, and results. Gastroenterology 2017;152:1752-64.
PUBMED | CROSSREF
12. Bray GA, Frühbeck G, Ryan DH, Wilding JP. Management of obesity. Lancet 2016;387:1947-56.
PUBMED | CROSSREF
13. Fock KM, Khoo J. Diet and exercise in management of obesity and overweight. J Gastroenterol Hepatol 2013;28 Suppl 4:59-63.
PUBMED | CROSSREF
14. Contento IR. Nutrition education: linking research, theory, and practice. Asia Pac J Clin Nutr 2008;17 Suppl 1:176-9.
PUBMED

https://doi.org/10.7762/cnr.2019.8.3.171

15. Wang H, Song Z, Ba Y, Zhu L, Wen Y. Nutritional and eating education improves knowledge and practice of patients with type 2 diabetes concerning dietary intake and blood glucose control in an outlying city of China. Public Health Nutr 2014;17:2351-8.
PUBMED | CROSSREF

16. Yuan C, Lai CW, Chan LW, Chow M, Law HK, Ying M. The effect of diabetes self-management education on body weight, glycemic control, and other metabolic markers in patients with type 2 diabetes mellitus. J Diabetes Res 2014;2014:789761.
PUBMED | CROSSREF

17. Lim HM, Park JE, Choi YJ, Huh KB, Kim WY. Individualized diabetes nutrition education improves compliance with diet prescription. Nutr Res Pract 2009;3:315-22.
PUBMED | CROSSREF

18. Wagner MG, Rhee Y, Honrath K, Blodgett Salafia EH, Terbizan D. Nutrition education effective in increasing fruit and vegetable consumption among overweight and obese adults. Appetite 2016;100:94-101.
PUBMED | CROSSREF

19. Mohammadshahi M, Haidari F, Karandish M, Ebrahimi S, Haghighizadeh MH. A randomized clinical trial of nutrition education for improvement of diet quality and inflammation in Iranian obese women. J Nutr Metab 2014;2014:605782.
PUBMED | CROSSREF

20. Pimentel GD, Portero-McLellan KC, Oliveira EP, Spada AP, Oshiiwa M, Zemdegs JC, Barbalho SM. Long-term nutrition education reduces several risk factors for type 2 diabetes mellitus in Brazilians with impaired glucose tolerance. Nutr Res 2010;30:186-90.
PUBMED | CROSSREF

21. Gibson AA, Sainsbury A. Strategies to improve adherence to dietary weight loss interventions in research and real-world settings. Behav Sci (Basel) 2017;7:44.
PUBMED | CROSSREF

22. de Vos BC, Runhaar J, van Middelkoop M, Krul M, Bierma-Zeinstra SM. Long-term effects of a randomized, controlled, tailor-made weight-loss intervention in primary care on the health and lifestyle of overweight and obese women. Am J Clin Nutr 2016;104:33-40.
PUBMED | CROSSREF

23. Marklund M, Magnusdottir OK, Rosqvist F, Cloetens L, Landberg R, Kolehmainen M, Brader L, Hermansen K, Poutanen KS, Herzig KH, Hukkanen J, Savolainen MJ, Dragsted LO, Schwab U, Paananen J, Uusitupa M, Åkesson B, Thorsdottir I, Risérus U. A dietary biomarker approach captures compliance and cardiometabolic effects of a healthy Nordic diet in individuals with metabolic syndrome. J Nutr 2014;144:1642-9.
PUBMED | CROSSREF

24. Vincent-Baudry S, Defoort C, Gerber M, Bernard MC, Verger P, Helal O, Portugal H, Planells R, Grolier P, Amiot-Carlin MJ, Vague P, Lairon D. The Medi-RIVAGE study: reduction of cardiovascular disease risk factors after a 3-mo intervention with a Mediterranean-type diet or a low-fat diet. Am J Clin Nutr 2005;82:964-71.
PUBMED | CROSSREF

25. Kristensen M, Pelletier X, Ross AB, Thielecke F. A high rate of non-compliance confounds the study of whole grains and weight maintenance in a randomised intervention trial-the case for greater use of dietary biomarkers in nutrition intervention studies. Nutrients 2017;9:55.
PUBMED | CROSSREF

26. Salinardi TC, Batra P, Roberts SB, Urban LE, Robinson LM, Pittas AG, Lichtenstein AH, Deckersbach T, Saltzman E, Das SK. Lifestyle intervention reduces body weight and improves cardiometabolic risk factors in worksites. Am J Clin Nutr 2013;97:667-76.
PUBMED | CROSSREF

27. Matthews DR, Hosker JP, Rudenski AS, Naylor BA, Treacher DF, Turner RC. Homeostasis model assessment: insulin resistance and β-cell function from fasting plasma glucose and insulin concentrations in man. Diabetologia 1985;28:412-9.
PUBMED | CROSSREF

28. Nazare JA, Smith J, Borel AL, Alméras N, Tremblay A, Bergeron J, Poirier P, Després JP. Changes in both global diet quality and physical activity level synergistically reduce visceral adiposity in men with features of metabolic syndrome. J Nutr 2013;143:1074-83.
PUBMED | CROSSREF

29. Kim J, Bea W, Lee K, Han J, Kim S, Kim M, Na W, Sohn C. Effect of the telephone-delivered nutrition education on dietary intake and biochemical parameters in subjects with metabolic syndrome. Clin Nutr Res 2013;2:115-24.
PUBMED | CROSSREF

30. Arab A, Askari G, Golshiri P, Feizi A, Hekmatnia A, Iraj B, Nourian M. The effect of a lifestyle modification education on adiposity measures in overweight and obese nonalcoholic fatty liver disease patients. Int J Prev Med 2017;8:10.
PUBMED | CROSSREF

31. Pinho CPS, Diniz ADS, Arruda IKG, Leite APDL, Rodrigues IG. Effects of weight loss on adipose visceral and subcutaneous tissue in overweight adults. Clin Nutr 2018;37:1252-8.
PUBMED | CROSSREF

32. Liu RH, Wharton S, Sharma AM, Ardern CI, Kuk JL. Influence of a clinical lifestyle-based weight loss program on the metabolic risk profile of metabolically normal and abnormal obese adults. Obesity (Silver Spring) 2013;21:1533-9.
PUBMED | CROSSREF

33. Yeo R, Yoon SR, Kim OY. The association between food group consumption patterns and early metabolic syndrome risk in non-diabetic healthy people. Clin Nutr Res 2017;6:172-82.
PUBMED | CROSSREF

34. Jane M, Hagger M, Foster J, Ho S, Kane R, Pal S. Effects of a weight management program delivered by social media on weight and metabolic syndrome risk factors in overweight and obese adults: a randomised controlled trial. PLoS One 2017;12:e0178326.
PUBMED | CROSSREF

35. Mummah S, Robinson TN, Mathur M, Farzinkhou S, Sutton S, Gardner CD. Effect of a mobile app intervention on vegetable consumption in overweight adults: a randomized controlled trial. Int J Behav Nutr Phys Act 2017;14:125.
PUBMED | CROSSREF

36. Leung AW, Chan RS, Sea MM, Woo J. An overview of factors associated with adherence to lifestyle modification programs for weight management in adults. Int J Environ Res Public Health 2017;14:922.
PUBMED | CROSSREF

37. Busnello FM, Bodanese LC, Pellanda LC, Santos ZE. Nutritional intervention and the impact on adherence to treatment in patients with metabolic syndrome. Arq Bras Cardiol 2011;97:217-24.
PUBMED | CROSSREF

38. Rodriguez-Cano A, Mier-Cabrera J, Balas-Nakash M, Muñoz-Manrique C, Legorreta-Legorreta J, Perichart-Perera O. Dietary changes associated with improvement of metabolic syndrome components in postmenopausal women receiving two different nutrition interventions. Menopause 2015;22:758-64.
PUBMED | CROSSREF

39. Karintrakul S, Angkatavanich J. A randomized controlled trial of an individualized nutrition counseling program matched with a transtheoretical model for overweight and obese females in Thailand. Nutr Res Pract 2017;11:319-26.
PUBMED | CROSSREF

40. Kim BR, Seo SY, Oh NG, Seo JS. Effect of nutrition counseling program on weight control in obese university students. Clin Nutr Res 2017;6:7-17.
PUBMED | CROSSREF