Beneficial Effects of a Dietary Approaches to Stop Hypertension Eating Plan on Features of the Metabolic Syndrome

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OBJECTIVE — To determine the effects of a Dietary Approaches to Stop Hypertension (DASH) eating plan on metabolic risks in patients with the metabolic syndrome.

RESEARCH DESIGN AND METHODS — This was a randomized controlled outpatient trial conducted on 116 patients with the metabolic syndrome. Three diets were prescribed for 6 months: a control diet, a weight-reducing diet emphasizing healthy food choices, and the DASH diet with reduced calories and increased consumption of fruit, vegetables, low-fat dairy, and whole grains and lower in saturated fat, total fat, and cholesterol and restricted to 2,400 mg Na. The main outcome measures were the components of the metabolic syndrome.

RESULTS — Relative to the control diet, the DASH diet resulted in higher HDL cholesterol (7 and 10 mg/dl), lower triglycerides (−18 and −14 mg/dl), systolic blood pressure (SBP) (−12 and −11 mmHg), diastolic blood pressure (−6 and −7 mmHg), weight (−16 and −14 kg), fasting blood glucose (FBG) (−15 and −8 mg/dl), and weight (−16 and −15 kg), among men and women, respectively (all $P < 0.001$). The net reduction in triglycerides (−17 and −18 mg/dl), SBP (−11 and −11 mmHg), diastolic blood pressure (−5 and −6 mmHg), and FBG (−4 and −6 mg/dl), weight (−16 and −15 kg), and increase in HDL (5 and 10 mg/dl) among men and women, respectively, was higher in the DASH group (all $P < 0.05$). The weight-reducing diet resulted in significant change in triglycerides (−13 and −10 mg/dl), SBP (−6 and −6 mmHg), and weight (−13 and −12 kg) among men and women, respectively (all $P < 0.05$).

CONCLUSIONS — The DASH diet can likely reduce most of the metabolic risks in both men and women; the related mechanisms need further study.

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The metabolic syndrome is a clustering of metabolic abnormalities and cardiovascular risk factors that occur in individuals with impaired insulin sensitivity (1,2). Existing data suggest that the incidence is rising at an alarming rate (3,4). In Tehran, Iran, it has been estimated to occur in >30% of adults (5), a prevalence significantly higher than that of most developed countries (6). In choosing a therapeutic diet for metabolic syndrome, all the abnormalities of the metabolic syndrome should be taken into account (7,8). Most patients with the metabolic syndrome are overweight or obese, especially upper-body obese (9,10). Therefore, basic weight reduction should be recommended (11). Weight reduction usually improves insulin sensitivity and all the metabolic and cardiovascular abnormalities linked with insulin resistance as well (12). Improvement of insulin sensitivity due to weight reduction is reported before (13). Although weight reduction is an effective way for the treatment of the metabolic syndrome, intervention studies are still needed to determine a specific therapeutic diet for the metabolic syndrome (7). Esposito et al. (14) reported that a Mediterranean-style diet might be effective in reducing the prevalence of the metabolic syndrome. Riccardi and Rivellese (7) introduced a diet with high amounts of vegetables, fruit, and legumes as well as reductions in saturated fat, salt, and alcohol as an optimal diet for the metabolic syndrome.

The Dietary Approaches to Stop Hypertension (DASH) research group (15) has determined that the DASH trial, which is a diet rich in fruits, vegetables, and low-fat dairy foods (16), lowers blood pressure (17–19) and has suitable effects on blood lipids (20). Since there are no reports about the effect of the DASH diet on metabolic syndrome, this study was conducted during phase 2 of the Tehran Lipid and Glucose Study (TLGS) (21) to assess the effect of the DASH diet on patients with the metabolic syndrome.

RESEARCH DESIGN AND METHODS

This study includes 116 participants (34 men and 82 women) recruited from among participants of the TLGS (21). All TLGS participants were residents of district 13 of Tehran. We divided this district into three subareas, of which one was further away from the two other areas and was considered as the case area, consisting of 5,000 subjects. All people in the case area with serum lipid or glucose abnormalities or high blood pressure were invited to the diet therapy clinic. Among the invitees who accepted, subjects with the metabolic syndrome were randomly divided into two groups: DASH and weight reducing. From the two other areas, which constituted the control group, we invited those subjects with metabolic syndrome who were matched with cases for confounder variables (Fig. 1).

The study participants were overweight or obese, had not participated in weight-reduction programs during the previous 6 months, and had maintained a stable weight (±1 kg). Each patient was asked to complete a personal health and medical history questionnaire that served as a screening tool.

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Abbreviations: DASH, Dietary Approaches to Stop Hypertension; DBP, diastolic blood pressure; SBP, systolic blood pressure; TLGS, Tehran Lipid and Glucose Study.

A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

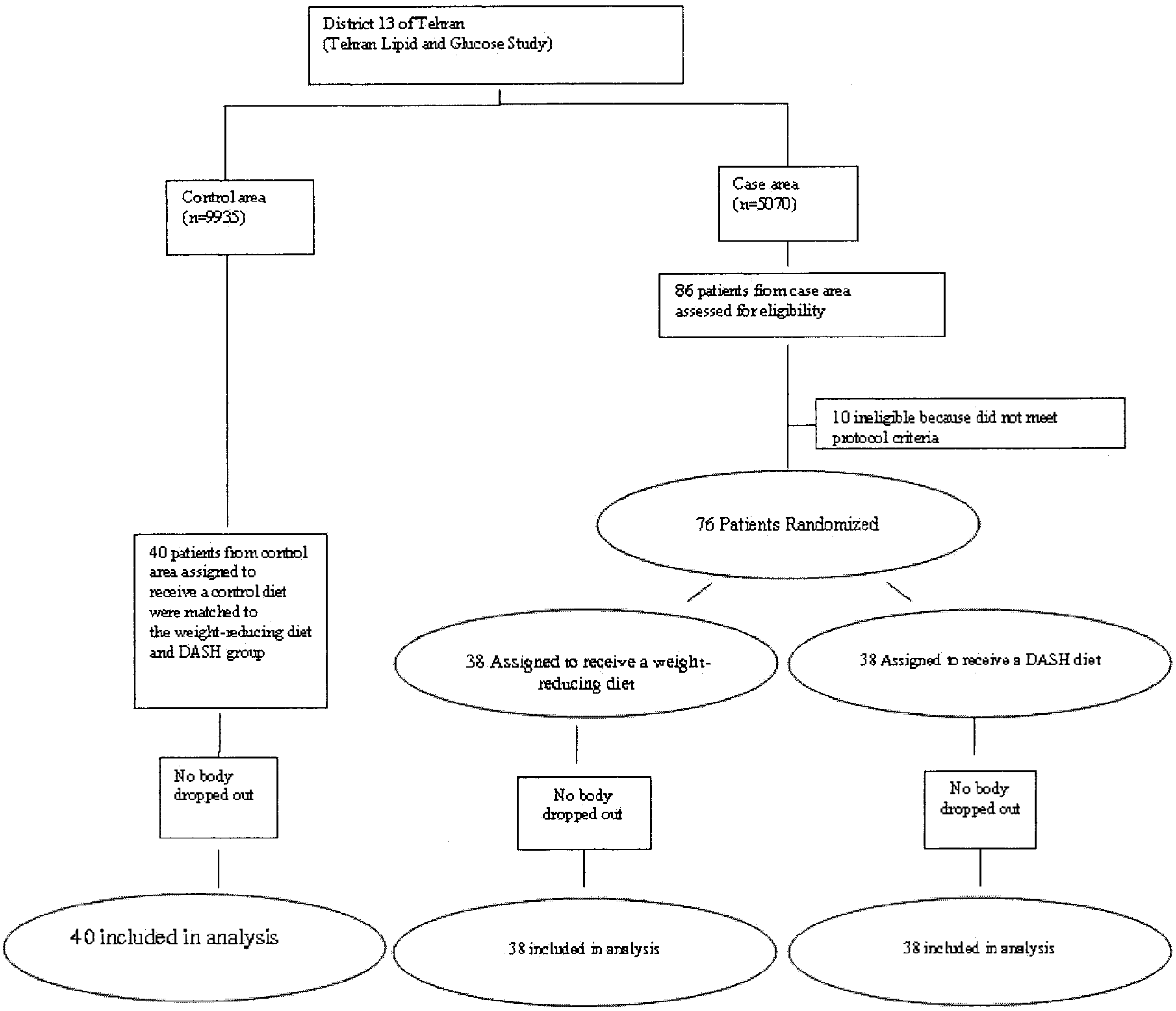

Figure 1—*Chart of the progression of patients through the trial. All TLGS participants were residents of district 13 of Tehran. We divided this district into three subareas, of which one was further away from the two other areas and was considered as the case area, consisting of 5,000 subjects. All people in the case area with serum lipid or glucose abnormalities or high blood pressure were invited to the nutrition clinic. Among the invitees who accepted, subjects with metabolic syndrome were randomly divided to two groups: DASH and weight reducing. From the two other areas that constituted the control group, we invited those subjects with metabolic syndrome who were matched with cases for confounder variables. All patients completed the entire study protocol. All of the patients were included in the data analysis, and there were no deviations from the intended protocol.*

To be enrolled in the study, patients had to have three or more of the following criteria to be diagnosed as having metabolic syndrome. Metabolic syndrome was defined according to Adult Treatment Panel III criteria (2): *1*) abdominal adiposity (defined as waist circumference >102 cm [men] or >88 cm [women]), *2*) low levels of serum HDL cholesterol (<40 mg/dl [men] or < 50 mg/dl [women]), *3*) hypertriglyceridemia (triacylglycerol level of ≥150 mg/dl), *4*) elevated blood pressure (≥130/85 mmHg), and *5*) impaired glucose homeostasis (fasting plasma glucose concentration of ≥110 mg/dl). Patients were excluded if they had cardiovascular disease, psychiatric problems, smoked, or took any medication affecting nutrient metabolism, blood lipids, and blood pressure or any vitamin and mineral supplements and antacids containing magnesium or calcium. The proposal of this study was approved by the research council of the Endocrine Research Center of Shaheed Beheshti University of Medical Sciences, and informed written consent was obtained from each subject.

Cases were randomly assigned to the two dietary patterns: weight-reduction diet and the DASH diet using a computer-generated random number sequence. The nutritionist who prescribed the diets had to be aware of the group assignment. Laboratory staff members were not aware of the patients' group assignments. Diets were offered according to specific individualized programs at the end of run-in (baseline).

Control diet

The control group was not given a diet prescription and was simply instructed to "eat as usual." Their eating patterns reflected the consumption of macronutrients, fruit, vegetables, and dairy products typical of what many Tehranians eat (carbohydrates, 50–60%; proteins, 15–20%; and total fat, <30%; mostly saturated, using 2–3 servings of fruits, 3 servings of vegetable, and 1 serving of dairy, mostly not low fat) (22).

Weight-reducing diet

This group was given general oral and written information about healthy food choices and a diet 500 kcal less than their caloric needs according to their weight. Macronutrient composition of the diet was similar to the control. Calcium intake, dairy, nut, and legumes content of this diet was lower than DASH. In addition, there were higher amounts of red meat, fat, saturated fat, cholesterol, and sweets in the weight-reducing diet compared with DASH.

DASH

This group ate a diet with 500 kcal less than their caloric needs, which was increased in fruit, vegetables, and low-fat dairy products and lower in saturated fat, total fat, and cholesterol, containing more whole grains and fewer refined grains, sweets, and red meat. The calcium, potassium, and magnesium of the DASH diet were higher. The DASH diet contained 2,400 mg Na per day (23). The servings, mentioned in the publication of the National Institutes of Health regarding the DASH eating plan, were used as a practical guideline. Lower consumption of meat and higher consumption of low-fat dairies, vegetable, fruit, whole-grain cereals, and legumes distinguish between the DASH trial and the weight-reduction diet. Table 1 shows the nutrients and food groups consumed during intervention period. We determined the caloric needs for each person individually according to the equation from the Institute of Medicine, Food, and Nutrition board (24). The patients had been visited monthly; each session for a patient was 45–60 min. They were in touch with the nutritionist by phone every day. Behavioral and psychological counseling was offered. The nutritionist explained the benefits of each diet for patients and told them if they continued these diets, related metabolic abnormalities might be controlled. The diets were individually prescribed using a calorie count system, and an exchange list was given to each patient for exchanging food items and counting the calories. A nutritionist educated subjects on how to use the exchange list and write food diaries. Every patient had to bring his 3-day diet records every month, and the dairies were reviewed by study staff. A 7-day menu cycle with 21 meals at seven calorie levels (1,500, 1,800, 2,000, 2,300, 2,500, 2,800, and 3,000) was developed for each diet.

To maximize treatment fidelity, group discussions were conducted monthly. In these sessions, the food items that should be eaten in each diet were emphasized, and intervention patients received education in reducing dietary calories and diet compliance; patients were encouraged to follow their diets. The investigators randomly took part in the counseling sessions, controlled the messages that the nutritionist was giving to each group, and randomly questioned the patients about their diets. The patients' compliance was assessed by analyzing the three food record diaries monthly and the attendance at meetings and monthly visits.

Study procedures

During the 3 weeks of run-in and 6 months of intervention feeding, the clinical center followed patients every month. We conducted a run-in to homogenize in the consumption of macronutrients and base of diets. In this period, patients consumed a control diet. The measurements were obtained before run-in, end of run-in (baseline), and then each month during the 6 months of the study period except for blood tests, which were repeated every 3 months.

Participants were requested not to change their habitual levels of physical activity for the duration of the study. Three-day records were used to compute intake at baseline and during intervention for each month. Nutrients were analyzed by Nutritionist III software, which was modified for Iranian foods.

Measurements

Weight was measured while the subjects were minimally clothed without shoes using digital scales and recorded to the nearest 0.1 kg. Height was measured in a standing position without shoes using a tape meter while the shoulders were in a normal state. Waist circumference was measured at the narrowest level and that of the hip at the maximum level over light clothing, using an unstretched tape meter, without any pressure to body surface and measurements were recorded to the nearest 0.1 cm, as reported earlier (25).

Twelve-hour fasting blood samples were collected into tubes containing 0.1% EDTA and then centrifuged at 4° C and 500g for 10 min to separate the plasma. Blood glucose was measured on the day of blood collection by the enzymatic colorimetric method using glucose oxidase. Triacylglycerol concentrations were measured by commercially available enzymatic reagents (Pars Azmoon, Tehran, Iran) adapted to selectra autoanalyzer. HDL cholesterol was measured after precipitation of the apolipoprotein B–containing lipoproteins with phosphotungistic acid. Inter- and intra-assay coefficients of variation were 1.6 and 0.6%, respectively, for triglycerides. Blood pressure was measured twice after the participants sat for 15 min (26). Additional covariate information regarding age, smoking habits (27), physical activity (28), medical history, and current use of medication (29) was obtained using validated questionnaires completed during the screening and every month as reported earlier.

Statistical methods

One-way ANOVA and χ^2 tests were used to determine the significance of any baseline differences between diet groups. Data were analyzed by intention to treat. We compared data at baseline, after 3 months, and again after 6 months separately for each diet by using repeated-measurement ANOVA for women and Friedman's for men. For reporting "net of control" standard linear regression techniques, adjustments for change in control group and change in weight were used. We built dummy variables for using or not using the three diets. The outcome measures were the changes in lipids from the end of run-in to the end of the intervention. For comparing the prevalence of metabolic syndrome between the DASH and the weight-reducing diet, we used the χ^2 test. All analyses were conducted using SPSS version 9.0 (SPSS, Chicago, IL).

RESULTS — The participant's mean age was 41.2 ± 12.3 years. Means ± SD of BMI were 28.9 ± 9.8 kg/m^2 in men and 31.4 ± 10.8 kg/m^2 in women. Baseline characteristics of these participants did not differ significantly across the three diet groups (Table 1). Nutrient consumption in the three groups during the intervention period is shown in Table 1. Waist circumference, lipid profile, and fasting blood glucose (FBG) were higher in women than men. The mean change of the components of the metabolic syndrome and weight after 6 months of intervention compared with baseline in each of the diet group is shown in Table 2. Significant reductions in waist circumference and triacylglycerol ($P < 0.04$) were seen among those who consumed the weight-reducing diet. The DASH diet changed the mean of all the components of meta-

Table 1—*Baseline characteristics of participants of the diet therapy clinic of the TLGS according to diet group and nutrient content and food-group servings of menus, calculated separately by each group in baseline and intervention period*

	Control diet*	Weight-reducing diet†	DASH diet‡	All
n	40	38	38	116
Age (years)	41.3 ± 12.1§	41.2 ± 12.4	41.5 ± 12.5	41.2 ± 12.3
Women (%)	70	71	71	70
Smokers (%)	8	10	10	9
BMI (kg/m^2)	29.5 ± 9.9	29.9 ± 10.1	29.8 ± 10.3	29.7 ± 10.0
Physical activity (%)				
Very light	60.0	60.1	62.0	61.8
Light	38.0	39.9	38.0	36.2
Moderate	2.0	0	0	2.0
Education (%)				
Illiterate	15	14	15	14
High school diploma	73	75	75	74
University graduates	12	11	10	12
Job status (%)				
Retired	17.2	16.0	15.5	16.0
Housewife	27.6	57.1	55.1	56.6
Employed	21.2	25.0	26.1	25.4
Others	4.0	2.0	3.3	2.0
Medications				
Cholesterol lowering (%)	5	5	5	5
Estrogen replacement therapy (%)	5	5	5	5
Oral contraception (%)	7	7	7	7
Baseline period				
Baseline nutrient content (per day)‖				
Protein (% of energy)	15	15	15	
Total fat (% of energy)	31	30	30	
Saturated	14	13	13	
Polyunsaturated	7	7	7	
Monounsaturated	9	9	9	
Cholesterol (mg/dl)	302	308	309	
Carbohydrate (% of energy)	55	54	55	
Fiber (g)	10	10	10	
Baseline keys score¶	54.3	51.9	51.9	
Potassium (mg)	1,430	1,420	1,410	
Calcium (mg)	705	710	712	
Magnesium (mg)	180	179	176	
Baseline food groups (servings/day)#				
Fruit	2.4	2.3	2.3	
Vegetables	3.1	3.2	3.1	
Grains				
Total	8.0	8.0	8.0	
Whole	1.1	1.2	1.1	
Low-fat dairy	0.5	0.5	0.5	
Regular-fat dairy	0.5	0.5	0.5	
Nuts, seeds, and legumes	0.1	0.1	0.1	
Beef and ham	1.0	1.0	1.0	
Poultry and fish	0.6	0.6	0.6	
Fat and oils	7.0	7.0	7.0	
Sweets	2.5	2.5	2.5	
Intervention period				
Intervention nutrient content (per day)¶				
Protein (% of energy)	15	17	17	
Total fat (% of energy)	31	29	28	
Saturated	14	10	7	
Polyunsaturated	7	7	8	
Monounsaturated	9	9	10	

Table 1—*Continued*

	Control diet*	Weight-reducing diet†	DASH diet‡	All
Cholesterol (mg/dl)	319	249	181	
Carbohydrate (% of energy)	55	57	58	
Fiber (g)	10	21	29	
Keys score‖	55.0	41.2	28.2	
Potassium (mg)	1,400	3,492	4,456	
Calcium (mg)	700	799	1,202	
Magnesium (mg)	180	349	460	
Intervention food groups (servings/day)#				
Fruit	2.3	4.0	5.1	
Vegetables	3.0	4.1	4.4	
Grains				
Total	8.1	7.4	7.9	
Whole	1	3.4	4.1	
Low-fat dairy	0.4	1.5	2.2	
Regular-fat dairy	0.5	0.3	0.7	
Nuts, seeds, and legumes	0.1	0.4	0.8	
Beef and ham	1.1	1.4	0.8	
Poultry and fish	0.7	0.9	1.0	
Fat and oils	6.9	4.5	3.0	
Sweets	5.5	3.5	2.5	

*Control diet is a diet similar to what most Tehranians usually eat. †Weight-reducing diet is a diet with 500 kcal less than caloric needs, emphasizing healthy food choices. ‡DASH diet is a diet increased in fruit, vegetables, and low-fat dairy products and reduced in saturated fat, total fat, and cholesterol. §$\bar{X} \pm$ SD. ‖Nutrition content was calculated based on Nutritionist III (Version 7.0; N-Squared Computing, Salem, OR). ¶Calculated from individual intakes as estimated from study menus and daily diaries. Keys score is $1.35 \times (2S\text{-}P) + 1.5\sqrt{c}$, where *S* is percentage of energy from polyunsaturated fat and *C* is mg dietary cholesterol per 4,200 kJ. #Based on 8.4-MJ (2,000-kcal) menus.

bolic syndrome, significantly in both men and women, more than the weight-reducing diet. Some components of the metabolic syndrome that were not improved in the weight-reducing diet were improved in the DASH diet.

Figure 1 shows the chart of the progression of patients through the trial. There were no dropouts, and all of the patients completed the entire study protocol. All patients were included in the data analysis, and there were no deviations from the intended protocol.

Figure 2 shows the mean change (and 95% CI) of HDL cholesterol, FBG, triglycerides, SBP, DBP, weight, and waist circumference in the DASH and weight-reducing groups, relative to the control, in men (Fig. 2*A*) and women (Fig. 2*B*). The DASH diet resulted in higher HDL cholesterol (7 and 10 mg/dl), lower triglycerides (−18 and −14 mg/dl), SBP (−12 and −11 mmHg), DBP (−6 and −7 mmHg), weight (−16 and −14 kg), FBG (−15 and −8 mg/dl), and weight (−16 and −15 kg) among men and women, respectively (all $P < 0.001$). The weight-reducing diet resulted in significant change in triglycerides (−13 and −10 mg/dl), SBP (−6 and −6 mmHg), and weight (−13 and −12 kg) among men and women, respectively (all $P < 0.05$). The net reduction in triglycerides (−17 and −18 mg/dl), SBP (−11 and −11 mmHg), DBP (−5 and −6 mmHg), FBG (−4 and −6 mg/dl), and weight (−16 and −15 kg) and increase in HDL cholesterol (5 and 10 mg/dl) among men and women was higher in the DASH group (all $P < 0.05$).

The prevalence of metabolic syndrome decreased significantly ($P < 0.05$) in the DASH diet group compared with the weight-reduction and control diets (65% in DASH group compared with 81% in the weight-reducing and 100% in the control group after 6 months).

CONCLUSIONS

— In this study, the DASH diet was associated with improvement of the metabolic risks. Therefore, a DASH diet may be a safe strategy for the treatment of metabolic syndrome.

Improvements in the metabolic risks may be due to weight reduction. Although weight-reduction in the present study is responsible for the favorable outcomes, the significant effect of the DASH diet in reducing the metabolic risks was also seen after controlling the effect of weight reduction by ANCOVA. As the DASH diet excels compared with the weight reduction, paying attention to the nutrient content of the diet consumed also is of high importance.

As mentioned in previous studies by the DASH research group (15), DASH had a favorable effect on blood pressure (16,17–19) as well as blood lipids (20). Hypertension and lipid abnormalities are two important components of the metabolic syndrome and are related to other metabolic risks to some extent. The DASH diet contains a larger amount of dairy, which is inversely related to the metabolic syndrome (29). Calcium plays an important role in this mechanism (29). The product of a gene named "agouti," which is expressed in human adipocytes, stimulated calcium current into the cells and by its concurrent effect on lipolysis and lipogenesis, causes the deposition of fat on adipocytes. This product increases fatty acid synthatase activity and inhibits lipolysis by a calcium-dependent mechanism (30,31). The beneficiary effect of calcium on preventing fat accumulation may also be attributed to uncoupling protein (UCP_2) expression in white adipose tissue and hence thermogenesis (32). Because the DASH diet is restricted in sodium, it contains higher levels of calcium and po-

Table 2—*Median and means of the components of metabolic syndrome of men and women participants in diet therapy clinic from TLGS at baseline* and after 3 and 6 months of intervention by diet group*

Components of metabolic syndrome	Control diet†				Weight-reducing diet‡				DASH diet§			
	Baseline	After 3 months	After 6 months	P‖	Baseline	After 3 months	After 6 months	P‖	Baseline	After 3 months	After 6 months	P‖
Men												
n	12	12	12		11	11	11		11	11	11	
WC (cm)	104 (89, 116)	103 (89, 115)	103 (89, 119)	NS	105 (86, 117)	103 (85, 116)	100 (84, 114)	0.04	105 (83, 115)	102 (79, 111)	98 (76, 110)	0.03
Weight (kg)	84 (78, 93)	85 (77, 94)	84 (75, 93)	NS	86 (79, 92)	80 (74, 89)	73 (68, 79)	0.03	87 (78, 95)	80 (75, 89)	71 (67, 78)	0.03
HDL cholesterol (mg/dl)	33 (21, 39)	33 (22, 40)	34 (22, 40)	NS	34 (22, 39)	35 (23, 41)	35 (25, 40)	NS	33 (24, 40)	36 (28, 42)	40 (31, 46)	0.03
Triglycerides (mg/dl)	206 (163, 223)	208 (160, 219)	205 (159, 220)	NS	201 (166, 225)	192 (159, 219)	187 (157, 216)	0.04	203 (165, 221)	189 (154, 216)	185 (150, 215)	0.03
SBP (mmHg)	143 (126, 150)	142 (129, 153)	142 (128, 154)	NS	143 (125, 159)	139 (120, 149)	136 (118, 147)	0.04	145 (120, 156)	139 (115, 150)	133 (114, 148)	0.04
DBP (mmHg)	87 (76, 91)	85 ± 11 (75, 93)	86 (76, 92)	NS	88 (75, 90)	87 (73, 92)	87 (72, 89)	NS	87 (70, 91)	84 (66, 89)	81 (61, 84)	0.04
FBS (mg/dl)	99 (91, 107)	97 (91, 108)	99 (91, 108)	NS	98 (90, 109)	95 (88, 106)	94 (87, 107)	NS	97 (91, 110)	91 (84, 107)	84 (78, 103)	0.03
Women												
n	28	28	28		27	27	27		27	27	27	
Weight (kg)	70 ± 12	70 ± 11	71 ± 12	NS	70 ± 11	63 ± 8	58 ± 7	0.04	71 ± 10	63 ± 8	57 ± 6	0.03
WC (cm)	95 ± 16	95 ± 17	94 ± 17	NS	95 ± 16	93 ± 16	91 ± 15	0.04	95 ± 17	93 ± 17	90 ± 16	0.04
HDL cholesterol (mg/dl)	30 ± 7	31 ± 7	30 ± 7	NS	30 ± 7	31 ± 7	32 ± 7	NS	30 ± 7	37 ± 7	40 ± 7	0.02
Triglycerides (mg/dl)	230 ± 51	232 ± 51	234 ± 51	NS	229 ± 50	220 ± 51	216 ± 48	0.04	231 ± 49	221 ± 49	217 ± 48	0.04
SBP (mmHg)	142 ± 11	143 ± 11	141 ± 12	NS	144 ± 10	142 ± 9	141 ± 9	0.04	143 ± 10	137 ± 9	132 ± 8	0.03
DBP (mmHg)	85 ± 14	83 ± 13	84 ± 13	NS	85 ± 13	84 ± 12	83 ± 12	NS	85 ± 13	81 ± 12	78 ± 12	0.03
FBS (mg/dl)	3 ± 28	95 ± 25	94 ± 25	NS	95 ± 24	92 ± 23	90 ± 22	NS	96 ± 22	110 ± 35	106 ± 34	0.04

Data are median (25th, 75th percentiles) or means ± SD unless otherwise indicated. *Baseline values are not significantly different among different diet groups. †Control diet is a diet similar to what most Tehranians usually eat. ‡Weight-reducing diet is a diet with 500 kcal less than caloric needs, emphasizing healthy food choice. §DASH diet, a diet increased in fruit, vegetables, and low-fat dairy products and reduced in saturated fat, total fat, and cholesterol. ‖*P* values are results from Friedman's test among baseline after 3- and 6-month values. WC, waist circumference.

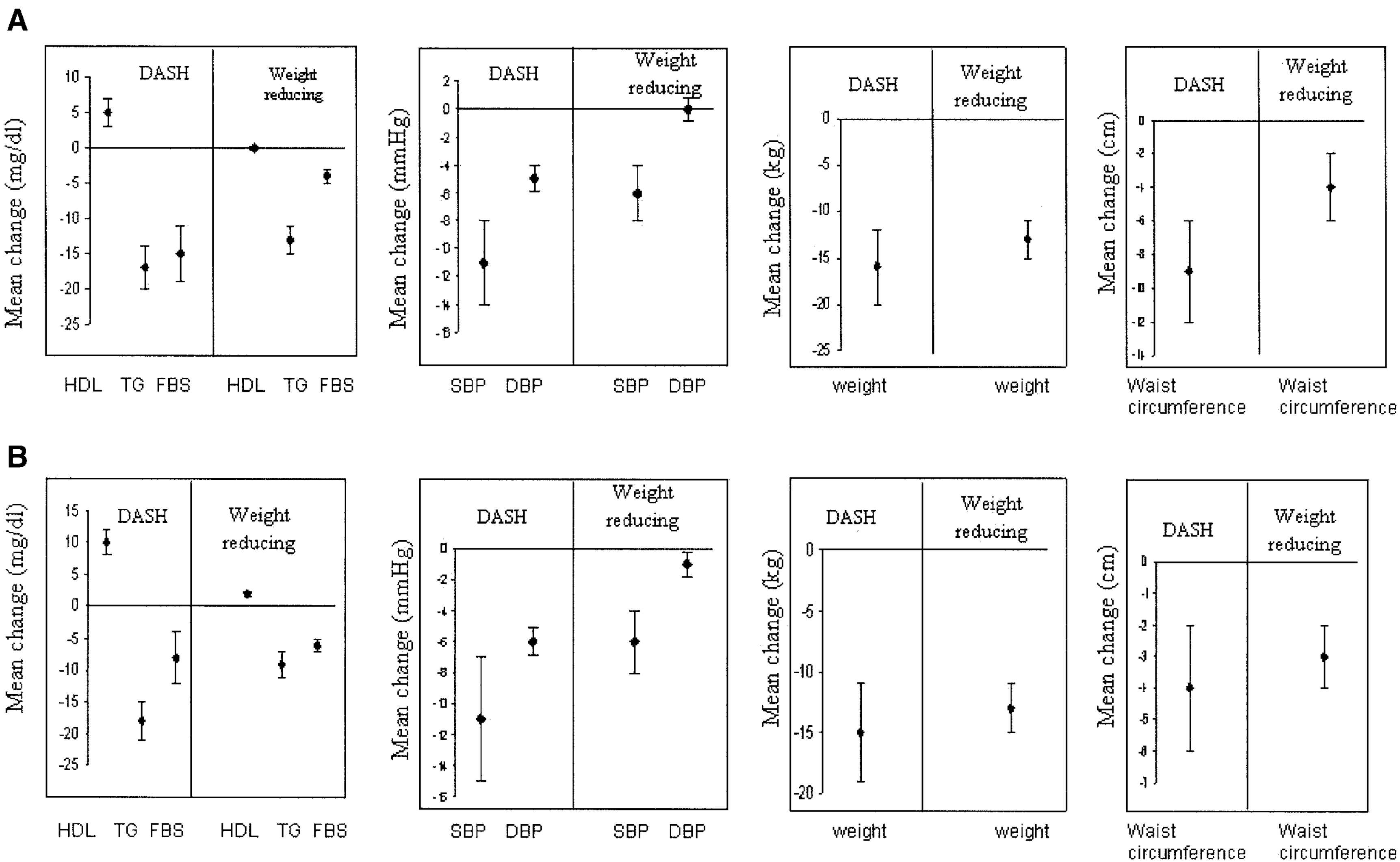

Figure 2—*Mean change (95% CI) in the lipid profiles, systolic and diastolic blood pressure, and weight and waist circumference in men (A) and women (B) after a diet with increased amounts of fruit, vegetables, and low-fat dairy products and reduced in saturated fat, total fat, and cholesterol (DASH diet) and after a weight-reducing diet relative to the control and adjusted for the weight change. For the DASH diet,* $P < 0.001$ *for all the metabolic risks. For the weight-reducing diet,* $P < 0.05$ *for triglycerides, SBP, and weight.*

tassium, which have an important role in regulating blood pressure. Dairy-rich diets reduced weight and waist more than calcium-rich ones. Therefore, other factors or substances, in addition to calcium, may play a role in prevention of fat accumulation, such as conjugated linolenic acid or milk protein (33,34).

Regarding HDL cholesterol, the baseline HDL cholesterol of the study participants was low, which may exacerbate the effect of consuming reduced-fat diets on HDL cholesterol for overweight people who lose weight (35–37). Insulin resistance is the fundamental metabolic defect that underlies metabolic syndrome (38). The DASH diet, with its high level of dairy that helps to improve insulin resistance (2), might have favorable effects on all features of metabolic defects.

Triacylglycerol was reduced in both the DASH and the weight-reducing diet in this study. It seems that weight reduction may be responsible for triacylglycerol reduction.

Esposito et al. (14) reported beneficial effects of a Mediterranean-style diet for patients with the metabolic syndrome. In the present study, more reduction in both systolic and diastolic blood pressure after 6 months' intervention was seen, which may be due to weight reduction along with the diet in the present study. Consuming 2,400 mg Na per day, higher amounts of calcium intake, increasing the consumption of low-fat dairies, and not using wine explain the difference between the DASH and Mediterranean diets. In the Mediterranean diet, there is no emphasis on dairy consumption. Olive oil is the most prominent of fat consumed in the diet, and meat is recommended monthly, whereas the DASH group consumed meat daily, although in small amounts; olive oil intake was lower in the DASH diet. We saw a favorable effect of the DASH diet on FBG, which may have resulted from the high fiber intake or from the consumption of whole grains (39).

The biological mechanisms whereby a DASH diet may exert its protective effect, although not clear, are likely to be many. Greater intakes of dietary fiber, folate, potassium, vitamin C, flavonols, flavanones, carotenoids, and phytosterol in the DASH diet might be responsible (40). Because of the phytochemicals, the DASH diet raises antioxidant capacity, lowers blood pressure, and reduces oxidative stress induced by acute hyperlipidemia (41). Therefore, antioxidants of the DASH diet may play an important role particularly in patients with the metabolic syndrome because reduced antioxidant capacity and oxidative stress represent a potential mechanism linking obesity to insulin resistance and cardiovascular diseases (42).

Eating large number of low–glycemic index foods (i.e., vegetables, whole grains, dairies) in the DASH eating pattern might be another responsible mechanism for its benefits. Besides the role of low–glycemic index foods in controlling the blood glucose (43–45), these foods may facilitate weight loss via their ability to enhance satiety and reduce subsequent food intake (46,47). Brand-Miller et al. (45) reported high–glycemic index foods adversely affect markers of the metabolic syndrome (triglycerides and HDL cholesterol).

One of the limitations of our study was the inability to determine whether individual components of the diet could account for the changes observed or whether the changes were due to the sum of all the dietary changes. The clinical usefulness of a whole-diet approach in the prevention of cardiovascular disease has been emphasized by Hu and Willett (48). A second limitation was the inability to report the soluble and insoluble fiber intakes separately in different diet groups. Third, because we had no *trans* fatty acid analysis in our nutrient analysis software, we could not report the *trans* fatty acid intake in the three groups separately. We had no data about the level of the serum insulin. Therefore, we were unable to calculate the possible changes in insulin resistance. Fourth, in this study, food was not provided to subjects.

We conclude that a DASH diet might be effective in reducing the metabolic risks; the related mechanism the measurements of inflammatory factors needs to be studied in future experimental designs.

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