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ORIGINAL ARTICLE

A web-based interactive lifestyle modification program improves lipid profile and serum adiponectin concentrations in patients with metabolic syndrome: the "Red Ruby" study

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Abstract The effectiveness of internet-based programs in prevention and treatment of metabolic syndrome has not been fully explored. In the present study, we investigate the effect of a 6-month web-based interactive lifestyle modification program on anthropometric variables and biochemical risk factors of cardiovascular disease. The study had been carried out among 160 patients with metabolic syndrome (intervention, $n=80$; control, $n=80$). The primary outcomes were change in anthropometric variables, fasting serum glucose (FSG), lipid profile, insulin sensitivity, and serum adiponectin concentrations in intervention and control groups. Significant reductions in anthropometric variables and serum lipids were observed in both intervention and control groups; however, reduction in waist-to-hip ratio (WHR), total cholesterol (TC), and low-density lipoprotein cholesterol (LDL-C) was only significant in intervention group ($P<0.05$). Reduction in anthropometric variables and serum triglyceride, systolic and diastolic blood pressure, and liver enzymes were significant in intervention and control groups ($P<0.05$) but in women decrease in FSG, TC, and LDL-C were only significant in intervention group ($P<0.05$). The present study showed that a web-based intervention was effective in weight loss and improving cardio-metabolic factors in patients with metabolic syndrome after a 6-month intervention.

Keywords Web-based · Interactive · Internet · Lifestyle modification · Metabolic syndrome · Lipid profile · Adiponectin

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Introduction

Metabolic syndrome (MetS) including insulin resistance, abdominal fat distribution, dyslipidemia, and hypertension is associated with higher mortality and morbidity from coronary heart disease (CHD) and cardiovascular disease (CVD) [1, 2]. In fact, in persons with MetS but without diabetes, the increased risk of CVD and CHD mortality remain [3]. Several previous studies reported that metabolic syndrome is associated with 3- to 4.3-fold increase in mortality from CVD [4] and subjects with metabolic syndrome are 3.5 to 5 times more likely to develop type 2 diabetes mellitus [5]. The third national health and nutrition examination survey (NHANES III) reported an alarming roughly 30 % of metabolic syndrome in middle-aged men [6]. The prevalence of metabolic syndrome in Iran is increasing in parallel of increasing in coronary artery disease (CAD); over the last 20 years, age-adjusted mortality rate from CAD has increased from 20 to 45 %. The age-adjusted prevalence of metabolic syndrome in Tehran Lipid and Glucose Study (TLGS) was 33.7 %; while the prevalence in women was higher than men (42 versus 24 %) [7].

Therapeutic approaches in metabolic syndrome are multifactorial regimens of modifications in dietary habits, physical activity schedule, and drug therapy. Dietary interventions include mostly from reducing saturated fat intake and promoting weight loss [8]. Several reports propose the Mediterranean-

style diet [9] and dietary approaches to stop hypertension (DASH) eating plan [10] to reduce vascular inflammation and improve endothelial function in metabolic syndrome. These recommendations are mainly based on consuming more fruits, vegetables, whole grains, and lower amounts of saturated fats. These dietary plans also encourage participants to have higher physical activity and more exercise [9, 10]. Changing dietary habits and physical activity behaviors may lead to a healthier weight, improved serum lipids, and lower blood pressure and blood glucose [11].

Recently, innovation in technology and home-based care led to new approaches for chronic disease management; web-based interventional programs provide using the Internet to record, monitor, and deliver health care [12]. These web-based interventions have created new interactions between patients and health care provider; patients are capable to self-monitor the disease from home and providers, on the other hand, can easily communicate with patients and feedback on the management of their disease [12]. Additionally, unlike face-to-face interventions, a web-based intervention is available in all hours a day and therefore could be used by a broad population [13].

Several previous reports investigated the efficacy of web-based intervention programs in the control and management of obesity [14, 15], type 2 diabetes mellitus [13, 16], and several other chronic diseases [17–19]. It has been reported that interactive web-based programs for lifestyle modification produce significantly more weight loss and greater reduction in waist circumference compared with the control group [15]. Accordingly, we expect that a web-based interventional program might be beneficial in improving the metabolic parameters and anthropometric variables in metabolic syndrome, which has not been evaluated yet; therefore, the primary objective of the present study is to evaluate the effect of a 6-month web-based interactive intervention program on the metabolic and anthropometric features in patients with metabolic syndrome.

Subjects and methods

Design and participants

This study was a part of the "Red Ruby" study [20]. Red Ruby is an interactive web-based intervention program. The intervention consisted of an Internet web page (http://www.Heartresearch.com) designed to improve self-management nutritional and physical activity behaviors in patients with metabolic syndrome in order to improve the subject's awareness about prevention of cardiovascular disease. The advertisement procedure was performed through the Internet. All of the participants who registered in the web site and met the inclusion criteria enrolled in the study. Inclusion criteria consisted from the following: having metabolic syndrome according to the National Cholesterol Education Program's Adult Treatment Panel III report (NCEP-ATP III) criteria [21] (except for waist circumference which was defined as ≥90 cm for both genders for Iranian population [22, 23]), accessibility to the Internet at home or work, having simple skills to work with the Internet, aged 20 years old and above, and living in Tehran. Exclusion criteria included the following: a) having history of cardiovascular diseases, type 2 diabetes mellitus, cancer, and renal diseases; b) being pregnant; c) taking medications for hypertension; d) taking medications for dislipidemia; and e) having incomplete registration form. Participants were randomly assigned into intervention and control groups. The allocation sequence was performed in sequentially numbered, opaque, sealed, and stapled envelopes. Randomization sequence was created by a biostatistician using the Excel software to assign participants to the study arms using a 1:1 allocation ratio with block size of 4.

Intervention and control groups

Participants in the both intervention and control groups were informed of their metabolic syndrome conditions and its components by an e-mail and encouraged to make appropriate changes in their dietary intake and physical activity in order to manage their disease. The participants in the intervention group received the username and password for log-in to the "My Healthy Heart Profile" and encouraged to regularly visit their own profile.

My Healthy Heart Profile program

This is an interactive web-based program that includes five parts:

1. Personal page on the main page included educational materials for prevention of cardiovascular disease and metabolic syndrome. These materials are free for download and print. Nutritional recommendations were based on dietary approach to stop hypertension (DASH).
2. Personal information included name, gender, age, weight, height, phone number, and e-mail addresses.
3. Inbox as an interactive section in the profile for personal questions. Participants in intervention arm were able to send personal questions and receive answers. We sent a calorie restricted tailored diet to all participants' inbox provided by a dietitian. The calorie restricted diet was based on each participant's calorie requirement according to his/her ideal body weight (IBW) and adjusted body weight (ABW) with less than 30 % of calories derived from fat, in accordance with the National Heart, Lung, and Blood Institute guidelines [24]. IBW was calculated with Hamwi equation [25]. ABW is defined as [(IBW+

25 % (actual body weight−IBW)]. We requested the intervention group to adhere the dieting program.

4. A cardiovascular risk estimation tool for 10 years (based on the Persian online version of Framingham Risk Score—FSR). The FSR comprises from six cardiovascular risk factors, including age (≥20), sex (male and female), total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), systolic blood pressure (SBP), and smoking habits. This is an interactive tool to calculate the risk score of heart attack risk score in every log-in. The estimated risk over 20 %, between 10 and 20 % and less than 10 % are considered as high, moderate, and low risk, respectively. Then users received an explanation regarding their score and were guided to educational materials on the personal homepage.
5. Anthropometric and clinical assays: in this section, user recorded periodic measurements of weight, waist circumference (WC), BMI, and blood pressure, TC, low-density lipoprotein cholesterol (LDL-C), HDL-C, TG, and fasting serum glucose (FSG).

The flowchart of the study has been presented in Fig. 1. This study has been approved by the ethics committee of Tabriz University of Medical Sciences (5/92/1228) and Tehran University of Medical Sciences (97/130/1736). The trial protocol has also been registered in IRCT (identifier: IRCT201111198132N1).

Anthropometric assessments

Anthropometric variables which included weight, height, WC, and BMI were evaluated at the beginning and end of the study. Weight was measured while subjects wearing light clothes. WC measured in horizontal plane, midway between the lowest rib and the iliac crest with a measuring tape in centimeter [26]. Waist-to-hip ratio was calculated by waist circumference divided by hip circumference.

Biochemical measurements

Biochemical measures include serum TC, LDL-C, HDL-C, FSG, TG, insulin, adiponectin, aspartate aminotransferase (AST), and alanine aminotransferase (ALT). Atherogenic index of plasma was calculated as log TG divided by HDL-C [27]. Assessment of insulin sensitivity was performed by the homeostasis model assessment of insulin resistance (HOMA-IR) based on fasting glucose and insulin measurements as follows: HOMA-IR: (glucose (mmol/l)×insulin (mU/l))/405 [28]. High HOMA-IR scores denote low insulin sensitivity. The Quantitative Insulin Check Index (QUICKI index) QUICKI was calculated as: 1/(log fasting insulin (U/l)+log fasting glucose (mg/dl)). Higher QUICKI values indicate greater insulin sensitivity [29].

Serum AST, ALT, TC, FSG, TG, HDL-C, and LDL were analyzed by enzymatic colorimetric method (Pars—Azmoon, Tehran—Iran). Serum insulin was analyzed with enzyme-linked immunosorbent assay method (ELISA—Monobind Insulin AccuBind, CA 92630, USA). The Sensitivity of this assay was 0.75 μIU/ml and mean inter- and intra-assay coefficient of variations (CV) were <9.8 and <8 %, respectively. Serum adiponectin was also analyzed by ELISA method (AviBion, Fin-01720 Vantaa, Finland) with sensitivity of <0.18 ng/ml and mean inter-and intra-assay CV of ≤12 and ≤10 %, respectively. All of the biochemical assessments were performed in Nutritional Research Center, Tabriz University of Medical Sciences and Heart Research Center, Tehran University of Medical Sciences.

Blood pressure measurements

Blood pressure was measured with mercury sphygmomanometer twice in the same arm after the individual seated at rest 10–15 min. The systolic and diastolic measurement represents the mean of two readings. All of the study measurements were performed by assessors who were blind to the group assignment.

Statistical analyses

Analysis of data was performed by SPSS software (statistical package for social analysis, version 18, SPSS Inc., Chicago, IL, USA). All comparison between treatment groups was based on intention-to-treat analysis using multiple imputation method. The normality of data was tested by Kolmogorov-Smirnov test. For parameters with normal distribution, independent Student's t test and for others the Mann-Whitney U test was used. The association between continuous variables was analyzed by Pearson correlation analysis and for categorical variables by chi-square test. The comparison of change in biochemical or anthropometric variables before and after analysis was performed by paired t test. McNemar's test was used for the comparison of matched-pair proportions. All data are expressed as means±SD. A two-sided P value less than 0.05 was considered significant. We determined the sample size according to the reference papers showing a 6-cm reduction in waist circumference after lifestyle modification [30, 31] to detect this difference with 90 % power and α-error of 5 %; a total of 80 individuals in each group were required. Primary outcome was to compare changes in anthropometric and biochemical variables between intervention and control subgroups. The secondary outcome was comparison of the difference in anthropometric and biochemical variables before and after intervention between two genders.

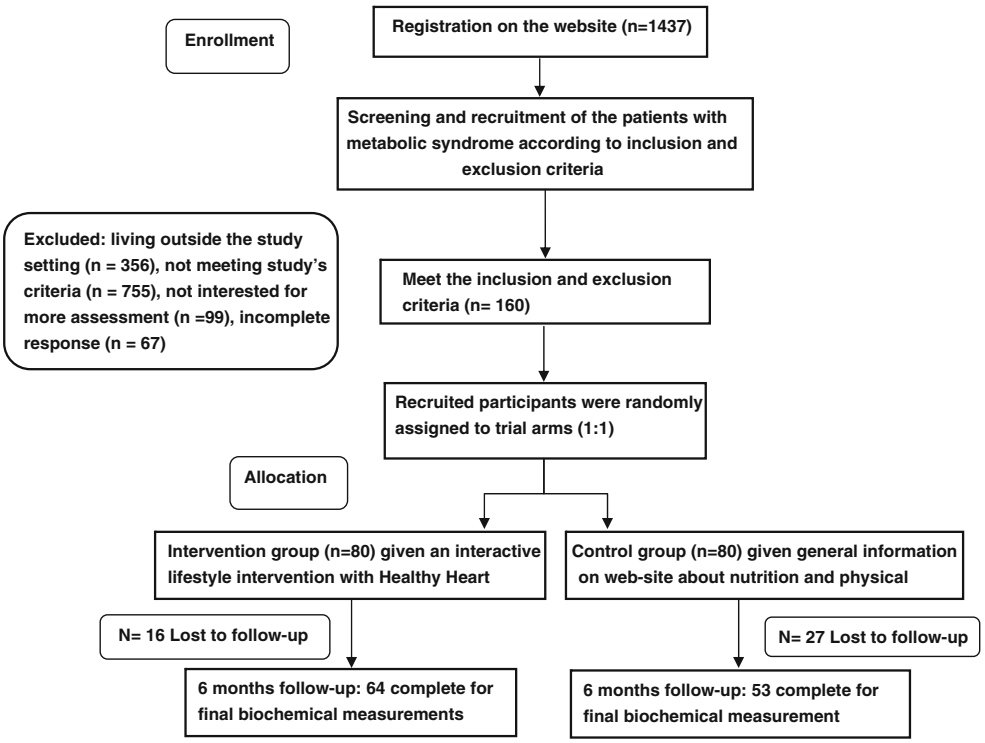

Fig. 1 Flowchart of the study for subject recruitment

Results

Baseline demographic characteristics of study participants are presented in Table 1. A total of 160 participants meeting inclusion criteria were enrolled in the study; however, there were 16 drop-outs in the intervention and 27 drop-outs in the control groups. Remaining participants include 64 participants in intervention and 53 participants in control groups who completed the study. Demographic characteristics were not different between intervention and control groups in men and women (Table 1).

Anthropometric and biochemical variables before and after intervention in overall participants are presented in Table 2. BMI; WC; and serum FSG, TC, TG, AST, and ALT; and AIP decreased and serum HDL and adiponectin concentrations increased in both intervention and control subgroups. However, decline in WHR, serum LDL, and TC were only significant in the intervention group ($P<0.05$).

In men, after a 6-month follow-up, anthropometric variables which include BMI, WC, and WHR decreased significantly in both intervention and control groups. Serum TG, AIP, AST, ALT SBP, DBP, and HOMA-IR decreased in both intervention and control groups in men. In women, like men, decrease in AIP, BMI, WC, WHR, SBP, and DBP and increase in HDL and adiponectin were in both groups; however, reduction in serum FSG, TC, LDL, and AST were only seen in the intervention group ($P=0.05$, Table 3).

We also compared mean value of change in anthropometric and biochemical variables in men and women (Table 4). The mean reduction in BMI in men and women of intervention groups were more pronounced than corresponding amounts in control groups ($P<0.001$ and $P=0.002$, respectively). The mean reduction in AIP in the intervention group was significantly higher ($P=0.05$); however, AIP reduction in female participants was not different between the intervention and control groups. There were approximately 10 and 11 mmHg reductions of DBP in men and women of intervention subgroups compared with 6.92 and 3.57 mmHg reductions in men and women of control groups ($P=0.01$ and $P=0.003$, respectively).

As shown in Table 5, higher log-in frequency was accounted for more reductions in serum insulin concentrations, HOMA-IR and more increases in QUICKI index in men of the intervention subgroup ($P<0.001$); there was no significant relationship between web site use and change in anthropometric or biochemical variables in women.

The prevalence of several components of metabolic syndrome including serum FSG≥110 mg/dl, TG≥150 mg/dl, SBP≥130, and DBP≥85 mmHg decreased significantly after a 6-month follow-up in both intervention and control groups (Table 6).

Discussion

We have found that a 6-month web-based intervention program providing nutritional recommendations for prevention of cardiovascular disease and improving

Table 1 Demographic characteristics of participants at baseline

Variable	Men			Women		
	Intervention	Control	*P*	Intervention	Control	*P*[a]
Number	43	39		21	14	
Age (years)	40.84±10.29	42.96±10.51	0.29	47.41±8.51	49.00±7.12	0.47
Current smoking [*n*(%)]	11 (25.58)	5 (28.62)	0.063	1 (4.76)	1 (7.14)	0.70
Educational attainment (years)						
12≤	32 (74.42)	24 (61.53)	0.079	10 (47.61)	3 (21.42)	0.79
12>	11 (25.58)	15 (38.46)		11 (52.38)	11 (78.57)	
Marital status [*n*(%)]						
Single	0	8 (20.51)	0.13	3 (14.28)	0	0.45
Married	43 (100)	29 (94.87)		18 (85.71)	13 (92.85)	
Widowed/divorced [*n*(%)]	0	2 (5.12)		0	1 (7.14)	
Family history of diabetes [*n*(%)]	8 (18.60)	8 (20.51)	0.35	6 (28.57)	5 (35.71)	0.54

Values represent percent of total individuals in each group

[a] Chi-square test results

physical activity can lead to significant reductions in WHR and reduction in serum TC and LDL-C in the intervention group compared with the control group. This study also showed that participants in intervention group experienced significantly more reductions in weight, BMI, and DBP than those in the control group. These findings confirm the study's initial hypothesis.

In the present study, we evaluated several anthropometric and biochemical factors which have not been evaluated in previous studies. Previous reports were mostly performed on patients with type 2 diabetes mellitus whereas the effect of a web-based interactive program in patients with metabolic syndrome has not been evaluated before. In the present study, patients with metabolic syndrome were recruited and the main

Table 2 Anthropometric and biochemical variables before and 6 months after intervention in overall participants

Variable	Intervention (*n*=64)			Control (*n*=53)		
	Before	After		Before	After	*P*
BMI (kg/m^2)	29.13±4.44	28.06±4.42	*<0.001*	29.48±3.29	29.10±3.07	*0.037*
WC (cm)	104.44±7.92	100.72±8.07	*<0.001*	105.64±8.31	103.35±7.35	0.29
WHR	0.93±0.08	0.91±0.05	*0.06*	0.94±0.05	0.92±0.04	*0.016*
FSG (mg/dL)	87.83±12.31	84.65±7.22	0.11	89.82±15.31	86.92±12.40	0.18
TC (mg/dL)	42.13±6.42	34.53±5.26	*0.01*	189.38±31.53	183.58±29.07	0.14
TG (mg/dL)	94.21±14.36	45.81±6.98	*<0.0001*	198.23±18.96	142.92±8.87	*0.001*
HDL (mg/dL)	39.16±6.74	44.65±5.03	*<0.0001*	38.56±8.96	43.38±10.18	*0.004*
LDL (mg/dL)	135.23±31.06	126.86±28.35	*<0.0001*	126.10±25.87	122.38±23.41	0.268
AIP	0.61±0.23	0.42±0.17	*<0.001*	0.64±0.27	0.47±0.23	*<0.001*
SBP (mmHg)	132.44±9.28	122.44±11.97	*0.0033*	133.20±16.95	124.48±7.59	*0.001*
DBP (mmHg)	88.72±6.46	78.72±7.40	*<0.0001*	88.20±8.69	81.28±6.03	*<0.001*
Insulin (μIU/mL)	16.97±2.78	8.33±3.64	0.25	23.92±3.86	18.16±9.99	0.41
HOMA-IR	3.39±0.98	1.79±0.81	0.22	5.18±0.63	3.76±4.47	*0.001*
QUICKI	0.33±0.04	0.35±0.03	0.28	0.34±0.06	0.34±0.04	0.15
AST (IU/l)	31±9.63	25.30±11.77	*0.051*	32.21±10.94	22.92±11.37	*0.02*
ALT (IU/l)	29.30±7	19±9.01	*0.008*	28.92±6.49	20.35±12.05	*0.04*
Adiponectin (ng/ml)	12.39±4.95	16.46±8.11	0.16	14.62±3.86	16.71±5.00	0.15

BMI body mass index, *WC* waist circumference, *WHR* waist-to-hip ratio, *FSG* fasting serum glucose, *TC* total cholesterol, *TG* triglyceride, *HDL* high-density lipoprotein cholesterol, *LDL* low-density lipoprotein cholesterol, *AIP* atherogenic index of plasma, *SBP* systolic blood pressure, *DBP* diastolic blood pressure, *HOMA-IR* homeostatic model assessment of insulin resistance, *QUICKI* quantitative insulin check index, *AST* aspartate aminotransferase, *ALT* alanine aminotransferase

Table 3 Anthropometric and biochemical variables before and 6 months after intervention in male and female participants

Variable	Men						Women					
	Intervention (n=43)			Control (n=39)			Intervention (n=21)			Control (n=14)		
	Before	After	P^a	Before	After	P^a	Before	After	P^a	Before	After	P^a
BMI (kg/m^2)	29.13±4.44	28.06±4.42	*<0.001*	29.48±3.29	29.10±3.07	*0.037*	31.35±4.27	29.22±4.15	*<0.001*	31.40±4.89	30.76±4.46	*0.016*
WC (cm)	104.44±7.92	100.72±8.07	*<0.001*	105.64±8.31	103.35±7.35	0.29	101.76±8.88	95.76±10.16	*<0.001*	103.00±8.62	99.35±7.69	*0.015*
WHR	0.93±0.08	0.91±0.05	*0.06*	0.94±0.05	0.92±0.04	*0.016*	0.90±0.10	0.89±0.06	0.36	0.91±0.03	0.85±0.044	*0.017*
FSG (mg/dL)	87.83±12.31	84.65±7.22	0.11	89.82±15.31	86.92±12.40	0.18	91.19±13.40	86.28±8.88	0.06	90.85±1.47	90.85±14.30	0.98
TC (mg/dL)	42.13±6.42	34.53±5.26	*0.01*	189.38±31.53	183.58±29.07	0.14	191.04±38.48	184±33.25	0.42	192.57±29.54	186.78±25.91	0.39
TG (mg/dL)	94.21±14.36	45.81±6.98	*<0.0001*	198.23±18.96	142.92±8.87	*0.001*	161.42±95.61	130.52±67.98	*0.018*	193.64±27.01	148.78±26.22	*0.009*
HDL (mg/dL)	39.16±6.74	44.65±5.03	*<0.0001*	38.56±8.96	43.38±10.18	*0.004*	42.09±8.14	49.80±10.23	*0.004*	49.35±13.12	50±11.49	0.85
LDL (mg/dL)	135.23±31.06	126.86±28.35	*<0.0001*	126.10±25.87	122.38±23.41	0.268	127.20±34.93	124.10±25.87	0.74	116.92±26.81	116.50±18.89	0.94
AIP	0.64±0.22	0.43±0.15	*<0.001*	0.66±0.27	0.49±0.21	*<0.001*	0.53±0.24	0.39±0.19	*0.004*	0.56±0.26	0.42±0.29	*0.016*
SBP (mmHg)	132.44±9.28	122.44±11.97	*0.0033*	133.20±16.95	124.48±7.59	*0.001*	130.04±6.24	118.57±11.08	*<0.001*	131.42±8.64	124.28±8.73	*0.004*
DBP (mmHg)	88.72±6.46	78.72±7.40	*<0.0001*	88.20±8.69	81.28±6.03	*<0.001*	89.47±5.89	78.09±6.20	*<0.001*	87.14±5.08	83.57±4.97	0.06
Insulin (μIU/ml)	16.97±2.78	8.33±3.64	0.25	23.92±3.86	18.16±9.99	0.41	11.13±3.77	9.86±5	0.46	14.22±8.44	12.20±7.78	0.72
HOMA-IR	3.39±0.98	1.79±0.81	0.22	5.18±0.63	3.76±4.47	*0.001*	2.23±0.97	2.19±0.89	0.71	2.66±0.98	3.18±0.70	0.68
QUICKI	0.33±0.04	0.35±0.03	0.28	0.34±0.06	0.34±0.04	0.15	0.34±0.02	0.35±0.05	0.34	0.34±0.04	0.35±0.08	0.93
AST (IU/l)	31±9.63	25.30±11.77	*0.051*	32.21±10.94	22.92±11.37	*0.02*	32.37±7.08	20.75±10.80	*0.03*	29±13.54	21.40±9.12	0.31
ALT (IU/l)	29.30±7	19±9.01	*0.008*	28.92±6.49	20.35±12.05	*0.04*	30.75±7.20	19.62±12.28	0.06	29.60±10.01	17.80±6.64	0.091
Adiponectin (ng/ml)	12.39±4.95	16.46±8.11	0.16	14.62±3.86	16.71±5.00	0.15	16.60±5.02	21.02±8.19	*0.04*	13.40±6.17	25.40±5.97	*<0.001*

Values are presented as mean±SD

BMI body mass index, *WC* waist circumference, *WHR* waist-to-hip ratio, *FSG* fasting serum glucose, *TC* total cholesterol, *TG* triglyceride, *HDL* high-density lipoprotein cholesterol, *LDL* low-density lipoprotein cholesterol, *AIP* atherogenic index of plasma, *SBP* systolic blood pressure, *DBP* diastolic blood pressure, *HOMA-IR* homeostatic model assessment of insulin resistance, *QUICKI* quantitative insulin check index, *AST* aspartate aminotransferase, *ALT* alanine aminotransferase

[a] The comparisons were carried out by paired *t* test or Wilcoxon signed-rank test

Table 4 Comparison of the changes in anthropometric and biochemical variables between subgroups

Variable	Men			Women		
	Intervention	Control		Intervention	Control	
Number	43	39		21	14	
	Change	Change	P^a	Change	Change	P^a
BMI (kg/m^2)	−1.07±0.25	−0.37±0.08	*<0.001*	−2.12±2.5	−0.63±0.73	*0.002*
WC (cm)	−3.72±2.5	−2.28±5.14	*0.037*	−6.00±4.47	−3.64±4.84	0.11
WHR	−0.018±0.05	−0.017±0.08	0.93	−0.012±0.10	−0.05±0.05	0.28
FSG (mg/dl)	−3.18±1.29	−2.89±1.32	0.92	−4.90±1.15	0.00±1.07	0.29
TC (mg/dl)	−16.34±4.17	−5.79±2.42	0.17	−7.04±3.9	−5.78±2.48	0.72
TG (mg/dl)	−60.58±8.44	−55.30±9.09	0.83	−30.90±0.49	−44.85±5.43	0.29
HDL (mg/dl)	5.48±6.73	4.82±9.82	0.71	7.71±1.08	0.64±1.26	0.087
LDL (mg/dl)	−8.37±2.49	−3.71±2.06	0.36	−3.10±4.22	−0.42±2.46	0.83
AIP	−0.20±0.02	−0.17±0.02	*0.05*	−0.14±0.02	−0.14±0.02	0.87
SBP (mmHg)	−10.00±10.74	−8.71±1.57	0.26	−10.47±1.04	−7.14±0.75	0.23
DBP (mmHg)	−10.00±6.7	−6.92±7.03	*0.01*	−11.38±7.38	−3.57±0.63	*0.003*
Insulin (μIU/ml)	−8.63±2.36	−5.76±2.41	0.95	−1.27±0.46	2.02±0.12	0.97
HOMA-IR	−1.59±0.43	−1.41±0.54	0.65	−0.13±1.02	0.52±0.22	0.72
QUICKI	0.018±0.05	−0.006±0.07	0.49	0.01±0.003	0.003±0.08	0.76
AST (IU/l)	−5.70±8.02	−9.28±1.32	0.46	−11.62±1.24	−7.06±1.45	0.60
ALT (IU/l)	−10.30±9.63	−8.57±1.45	0.74	−11.12±1.46	−11.80±1.90	0.93
Adiponectin (ng/ml)	4.07±0.97	2.09±0.48	0.52	4.42±0.45	2.43±0.45	*0.007*

Values are presented as mean±SD, Significance level was defined as $P<0.05$

BMI body mass index, *WC* waist circumference, *WHR* waist-to-hip ratio, *FSG* fasting serum glucose, *TC* total cholesterol, *TG* triglyceride, *HDL* high-density lipoprotein cholesterol, *LDL* low-density lipoprotein cholesterol, *SBP* systolic blood pressure, *DBP* diastolic blood pressure, *HOMA-IR* homeostatic model assessment of insulin resistance, *QUICKI* quantitative insulin check index, *AST* aspartate aminotransferase, *ALT* alanine aminotransferase

[a] The comparisons were carried out by paired *t* test or Wilcoxon signed-rank test

target of the current study was prevention of cardiovascular disease and type 2 diabetes mellitus. The finding of the present study was in consistent with previous reports using web-based interventions to provide health care for patients of chronic disease [12, 32, 33].

In a study by Bond et al. [12], a 6-month web-based intervention plus usual care compared with usual care alone reduced HbA1C, weight and cholesterol, and HDL-C in patients with type 2 diabetes mellitus. In another study, Moore T et al. [34] reported that an Internet-based nutrition education program in US employees is effective to reduce weight and blood pressure and improve their eating habits after 12 months of intervention. The same results were reported by McMahon GT [32] in patients with poorly controlled diabetes mellitus. Even though there were modifications in BMI, WC, DBP, and serum adiponectin concentrations in intervention and control subgroups, it should be remembered that these changes in the intervention group were more pronounced than in the control group. This fact suggests the possible role of interactive web-based education in improving anthropometric and metabolic parameters. These findings were in accordance of the Bond et al.'s report [12]. They reported that serum cholesterol and body weight decreased in both intervention and control groups; however, mean reduction in these parameters were greater in the intervention group ($P<0.05$). They also found that reductions in SBP and DBP were only seen in the intervention group and not in the control group. This inconsistency could be derived from the different protocol administered for the control group in Bond et al.'s study who have no access to the Internet and received only their standard diabetes care from their provider and no educational or training materials associated with the intervention were provided for them. Whereas our control group received e-mails every 3 weeks to visit the web site and read the general nutritional recommendations and lifestyle changes in addition to their standard usual care advices.

In the present study, almost two thirds of participants at baseline were men and the attrition rate among men [$n=24$ (23 %)] was lower than women [$n=18$ (34 %)]. It seems that men are more interested to participate in an Internet-based educational program than women. Therefore, our study disproves the previous studies by Oenema et al. [35] and Gold

Table 5 Correlation of number of log-ins and changes in anthropometric and biochemical variables in intervention group

Variable	Men		Women	
Number	43		21	
	r	*P*	*r*	*P*[a]
Δ BMI (kg/m^2)	0.03	0.84	0.17	0.43
Δ WC (cm)	0.002	0.98	0.08	0.72
Δ WHR	−0.18	0.32	0.02	0.93
Δ FSG (mg/dl)	0.17	0.30	−0.35	0.11
Δ TC (mg/dl)	−0.19	0.24	0.005	0.98
Δ TG (mg/dl)	0.07	0.64	0.18	0.41
Δ HDL (mg/dl)	0.14	0.39	0.08	0.72
Δ LDL (mg/dl)	−0.19	0.22	−0.29	0.2
Δ AIP	0.45	0.09	0.34	0.9
Δ SBP (mmHg)	−0.02	0.89	−0.003	0.98
Δ DBP (mmHg)	0.21	0.19	−0.008	0.73
Δ Insulin (μIU/ml)	−0.99	*<0.001*	0.54	0.16
Δ HOMA -IR	−0.99	*<0.001*	0.48	0.22
Δ QUICKI	0.99	*<0.001*	−0.51	0.19
Δ AST (IU/l)	0.15	0.76	−0.31	0.45
Δ ALT (IU/l)	0.8	0.06	0.16	0.7
Δ Adiponectin (ng/ml)	−0.15	0.06	−0.35	0.44

Values are presented as mean±SD, Δ Net difference between intervention and control groups

BMI body mass index, *WC* waist circumference, *WHR* waist-to-hip ratio, *FSG* fasting serum glucose, *TC* total cholesterol, *TG* triglyceride, *HDL* high-density lipoprotein cholesterol, *LDL* low-density lipoprotein cholesterol, *SBP* systolic blood pressure *DBP* diastolic blood pressure, *HOMA-IR* homeostatic model assessment of insulin resistance, *QUICKI* quantitative insulin check index, *AST* aspartate aminotransferase, *ALT* alanine aminotransferase

[a] Pearson correlation analysis

et al. [36] reporting the lower participation of men in health promotion behaviors. Higher familiarity with technology and higher attitude about the Internet in men are several possible reasons of their higher interest for using web-based programs [37]; moreover, this can be attributed to higher educational attainment of our male participants. We should also address the difference in the change in measured parameters between men and women, and change in anthropometric variables were not different between men and women; however, significant decrease in serum TC, FSG, and LDL-C and significant increase in serum adiponectin concentrations was only observed in women but not men. Similar to our study, previous reports also showed higher concentrations of serum adiponectin in women compared with that in men. Since higher adiponectin concentrations in serum is in close relationship with better glycemic control and favorable lipid profile [38, 39]; therefore, we can postulate that significant increase in serum adiponectin in women might be responsible in meaningful improvements in TC, LDL-C, and FSG in women.

The present study was limited to a small number of adults who have the ability to work with the Internet; also, the present study did not evaluate the long-term effectiveness of the web-based education on lifestyle change and nutritional modification. Another limitation of the current study was conducting in one of the most air polluted cities of Iran: Tehran. Air pollution is a potent factor in limiting the physical activity and walking among participants.

However, the strengths of this study should be encouraged: it was the first randomized clinical trial evaluating the effectiveness of a web-based interactive program for improving lifestyle habits in patients with metabolic syndrome; including both males and females in the current study is another potent strength which makes it more generalizable.

Table 6 The prevalence of metabolic syndrome ingredients according to the National Cholesterol Education Program's Adult Treatment Panel III Report (ATP III) criteria before and after 6 months web-based trial

Variable	Intervention (*n*=64)			Control (*n*=53)		
	Before *n* (%)	After *n* (%)	*P*[a]	Before *n* (%)	After *n* (%)	*P*[a]
WC (cm)≥90 cm	64 (100)	52 (81.25)	*0.004*	53 (100)	51 (96.22)	0.98
FSG (mg/dl)≥110 mg/dl	36 (56.25)	6 (9.37)	*<0.001*	36 (67.92)	16 (30.18)	*0.002*
TG (mg/dl)≥150 mg/dl	36 (56.25)	6 (9.37)	*<0.001*	36 (67.92)	15 (28.30)	*<0.001*
HDL (mg/dl)<40 mg/dl (male)	41 (64.02)	39 (60.93)	0.53	35 (66.03)	35 (66.03)	0.98
HDL (mg/dl)<50 mg/dl (female)	19 (29.68)	9 (14.06)	0.083	8 (15.09)	7 (13.20)	0.53
SBP (mmHg)≥130	64 (100)	19 (29.68)	*<0.001*	53 (100)	19 (35.84)	*<0.001*
DBP (mmHg)≥85	64 (100)	13 (20.31)	*<0.001*	53 (100)	22 (41.50)	*<0.001*

Values are presented as mean±SD

WC waist circumference, *FSG* fasting serum glucose, *TG* triglyceride, *HDL* high-density lipoprotein cholesterol, *SBP* systolic blood pressure, *DBP* diastolic blood pressure

[a] The comparisons were carried out by McNemar's test

In conclusion, in a 6-month web-based intervention program, significant reduction in WHR, TC, and LDL cholesterol in patients receiving interactive web-based lifestyle modification program was achieved. Further studies are needed to compare the effectiveness of the web-based nutrition and physical activity intervention programs with traditional face-to-face programs.

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

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