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Beneficial effects of Apple Cider Vinegar on weight management, Visceral Adiposity Index and lipid profile in overweight or obese subjects receiving restricted calorie diet: A randomized clinical trial

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ABSTRACT

A randomized, clinical trial was performed to examine whether Apple cider vinegar (ACV) can result in dietary modifications that provides beneficial effects on the management of body weight and serum metabolic profiles in overweight or obese individuals. The participants (n = 39) were randomly allocated into the ACV (subjected to a restricted calorie diet (RCD) with 250 kcal/day energy deficit and 30 mL/d of ACV)) or the control group (RCD only) for 12 weeks. The ACV significantly reduced body weight, BMI, Hip circumference, visceral adiposity index (VAI) and appetite score ($P \leq 0.00$). Furthermore, Plasma triglyceride (TG) and total cholesterol (TC) levels significantly decreased and high density lipoprotein cholesterol (HDL-C) concentration significantly increased in the ACV group in comparison to the control group ($P \leq 0.05$). Thus, ACV along with RCD can be considered as an effective strategy for reducing anthropometric parameters, TG and TC level, VAI, appetite and increasing HDL-C concentration in overweight or obese individuals.

1. Introduction

Obesity has become a critical challenge worldwide in the recent decades and is associated with many public health problems such as dyslipidemia, cardiovascular disease, and type 2 diabetes (Al-Kuraishy & Al-Gareeb, 2016; Health, 2000). The most effective strategies for the management of obesity are energy intake restriction, increased physical activity, behavioral modifications, pharmacotherapy, and bariatric surgery (Health, 2000). Unfortunately, these treatments have had a maximum success rate of only 21% (Wing & Hill, 2001).

Traditional and complementary medicine is becoming more popular worldwide generally due to fewer side effects (Ajaykumar, Anandarajagopal, Jainaf, Venkateshan, & Ananth, 2012). Apple cider vinegar (ACV) is widely used as a flavoring (or dressing) and preservative in foods. In addition, ACV is a traditional natural treatment that has two main active constituents including acetic acid (Kondo, Kishi, Fushimi, Ugajin, & Kaga, 2009) and polyphenolic compounds (Denis et al., 2013). Recently ACV has attracted a lot of interest for its beneficial effects on controlling body weight and visceral fat accumulation (Kondo et al., 2009). So far, a few animal studies and clinical trials have been performed investigating the effects of ACV on anthropometric measurements, body composition and plasma lipids. Some of these studies show that vinegar administration has favorable effects on anthropometric parameters especially body weight regulation (Kondo et al., 2009; Lim et al., 2009; Ok et al., 2013; Seo et al., 2014), whereas others did not find these effects (Lee et al., 2013; Park et al., 2014). In addition, the effects of vinegar on lipid parameters were contradictory in the previous studies (Kondo et al., 2009; Ok et al., 2013; Park et al., 2014; Seo et al., 2014). Furthermore, based on the current evidence, there is a general lack of research investigating the effects of ACV on plasma concentrations of neuropeptide-Y (NPY) which is the most potent orexigenic peptide, regulating food intake (Tatemoto, 2004). Moreover, it seems that evaluating the visceral adiposity index (VAI) is a beneficial marker determining adipose tissue dysfunction, in regards to subcutaneous and visceral adipose tissue in the abdominal region (Al-Kuraishy & Al-Gareeb, 2016). Therefore, the present study aimed to evaluate the impact of ACV along with restricted calorie diet (RCD) on the anthropometric measurements, body

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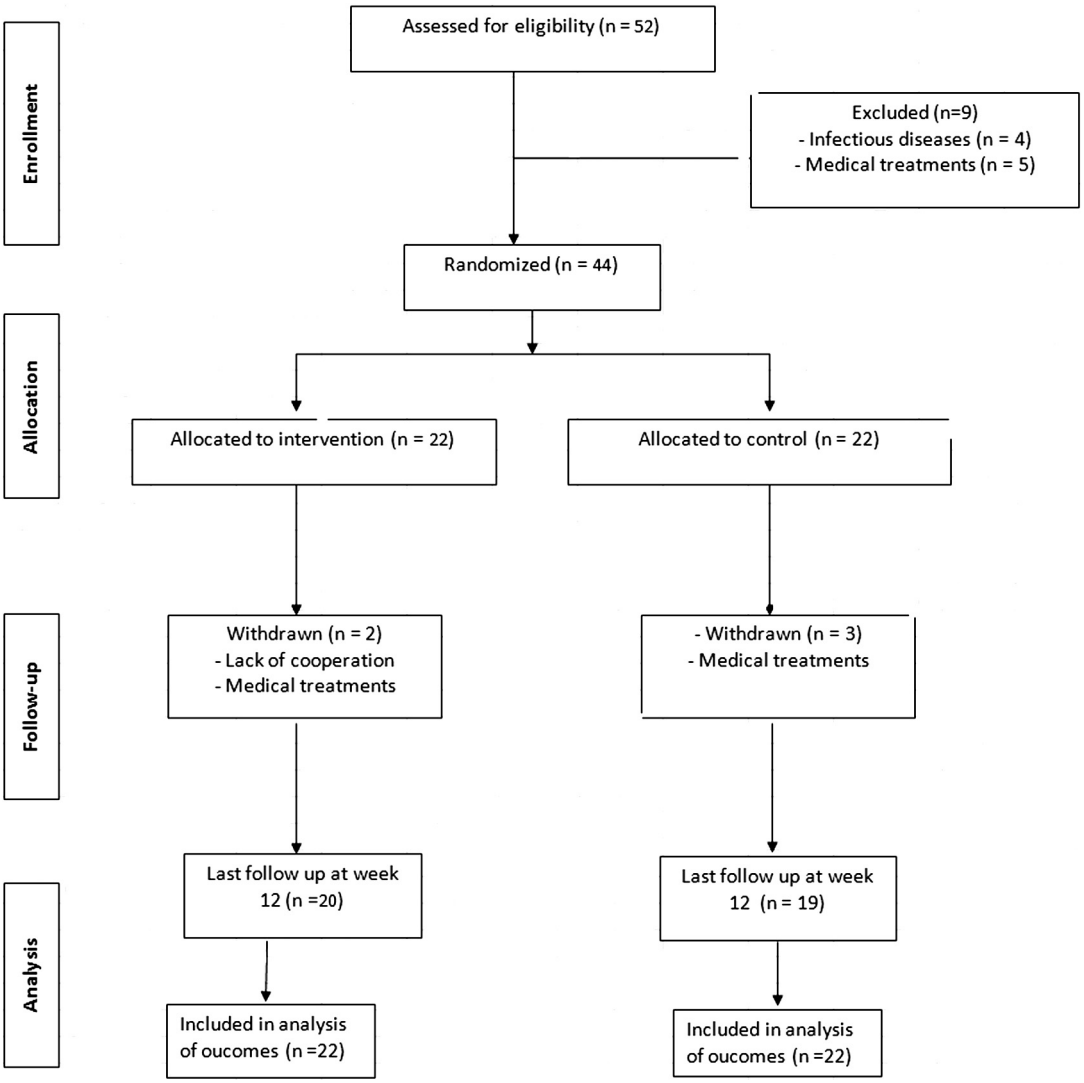

Fig. 1. Summary of the patient flow diagram.

Table 1
Baseline characteristics of subjects in ACV and control groups.

Characteristics	Control	ACV	*P* value**
Age (years)*	45 ± 11	42.5 ± 9	0.69
Sex (n/%)			
Male	3 (16)	4 (20)	0.43
Female	16 (84)	16 (80)	
Past experiences with weight-reducing treatment (n/%)	11 (58)	14 (70)	0.30

* Values are mean ± SD.
** $p < .05$ considered significant.

composition, VAI, plasma lipids, NPY, and appetite in overweight or obese individuals.

2. Methodology

2.1. Subjects and ethical aspects

A randomized, controlled trial conducted from October to December 2014, this study was not blinded as the subjects in the ACV group were aware of the nature of the samples due to the strong odor and taste. No odor masking techniques were used as the control group were only subjected to the RCD. In this two-arm parallel study with 9 kg difference detection and a pooled standard deviation of 9.8 kg (Kondo et al., 2009), the minimum sample size was estimated 19 at a power $(1 - \beta)$ of 80% ($\alpha = 0.05$). Forty-four metabolically healthy overweight or obese adults (men and women) with the body mass index (BMI) of more than 27 kg/m^2 (range 27–40) were selected using convenience sampling from the Specialized Clinic of Nutrition & Diet Therapy located in the Faculty of Nutrition Sciences and Food Technology of Shahid Beheshti University of Medical Sciences in Tehran, Iran.

Subjects enrolled in this study did not have infectious diseases, thyroid disorders, diabetes, or gastrointestinal diseases. In addition, patients who had regularly used ACV within one month prior to the beginning of the study were excluded.

The guidelines of the Helsinki Declaration was applied in this study and the Ethics Committee of the National Nutrition and Food Technology Research Institute of Iran has approved all proceedings. This clinical trial was registered at Iranian Registry of Clinical Trials (IRCT) under IRCT2013122815968N1.

2.2. Protocol

The Research Committee of the National Nutrition and Food Technology Research Institute of Iran has approved this study protocol. Informed consent was signed by all subjects before initiation of the

Table 2
Dietary intakes and physical activity in ACV and control groups.[1,a]

Variables	Study period			Changes during 12 weeks	*P* value*
	Baseline	Week 6	Week 12		
Energy (g/d)					
ACV	1750 ± 362	1463 ± 375	1461 ± 495	−289 ± 597	0.01
Control	1640 ± 461	1450 ± 357	1451 ± 458	−189 ± 499	0.12
P value**	0.31	0.78	0.98	0.93	
Protein (g/d)					
ACV	61 ± 12.3	54 ± 16.5	53.8 ± 18	−6.9 ± 17	0.07
Control	60 ± 19.6	61 ± 15	57.2 ± 20.6	−3.07 ± 22	
P value	0.62	0.31	0.60	0.58	0.6
Carbohydrate (g/d)					
ACV	233 ± 65	197 ± 60	203 ± 87	−30.3 ± 13	0.14
Control	224 ± 62	198 ± 55	207 ± 80	−16.9 ± 82	
P value	0.57	0.98	0.78	0.92	0.30
Fat (g/d)					
ACV	64 ± 18.5	51 ± 20.5	51.2 ± 18	−13.04 ± 25	0.03
Control	60 ± 20	44 ± 12	48.6 ± 15.6	−11.1 ± 22.3	0.02
P value	0.40	0.15	0.69	0.2	
SFA (g/d)					
ACV	16.2 ± 3.8	12.3 ± 4.3	12.3 ± 4	−3.9 ± 4.6	0.00
Control	14 ± 5.5	17 ± 16.4	13.3 ± 0.1	−0.73 ± 5.2	
P value	0.17	0.21	0.42	0.05	0.34
MUFA (g/d)					
ACV	17.3 ± 3.7	13.2 ± 4.7	12.7 ± 4.9	−4.5 ± 4.5	0.00
Control	15 ± 7	13.3 ± 4.7	11.8 ± 4	−3.2 ± 6.5	0.07
P value	0.07	0.64	0.66	0.16	
PUFA (g/d)					
ACV	26.8 ± 10.7	21.1 ± 9.5	20.1 ± 9.7	−6.7 ± 12.9	0.08
Control	21.3 ± 8.7	15.7 ± 6.3	16.1 ± 7.9	−5.1 ± 10.3	0.03
P value	0.08	0.07	0.17	0.92	
Cholesterol (mg/d)					
ACV	176 ± 77	150 ± 69	174 ± 95	−1.63 ± 114	0.45
Control	177 ± 73	198 ± 70	183 ± 95	6.5 ± 85	0.56
P value	0.82	0.07	0.76	0.93	
Fiber(g/d)					
ACV	14.5 ± 4.6	12 ± 5.3	11 ± 3.8	−3.2 ± 4.7	0.09
Control	16.5 ± 10.3	12 ± 3	18 ± 18.6	1.4 ± 19.3	0.21
P value				0.51	
Calcium (mg/d)					
ACV	599 ± 238	515 ± 172	576 ± 239	−22.3 ± 267	0.24
Control	569 ± 277	645 ± 261	621 ± 223	52 ± 274	0.37
P value	0.33	0.90	0.12	0.57	
Physical activity (metabolic equivalent –minute/week)					
ACV	189 ± 21	255 ± 41	257 ± 34	66 ± 4.5	0.12
Control	210 ± 24	267 ± 41	265 ± 39	57 ± 4	0.24
P value	0.49	0.68	0.50	0.31	

ACV: apple cider vinegar; SFA: saturated fatty acids; MUFA: monounsaturated fatty acid; PUFA: polyunsaturated fatty acid.
[1] All values are mean ± SD.
[a] $p < .05$ considered significant.
* Repeated measures ANOVA.
** Analysis of covariance for changes during 12 weeks (adjusted for body fat changes) & Student's *t*-test for variables.

study. The participants were randomly assigned to either ACV or the control group. This allocation was completed by block randomization, block size of 4 was chosen and possible balanced combinations with 2C (control) and 2 A (ACV) subjects, calculated as 6 blocks (AACC, ACAC, ACCA, CAAC, CACA, CCAA). Then, blocks were randomly chosen, based on a simple random sampling method to determine the assignment of all subjects into the groups. The block randomization was performed by a trained dietician. Furthermore, all procedures including implementation of the allocation sequence, participants registration, and allocating subjects to interventions were performed by a research director.

Subjects in the ACV group received 30 mL/day of apple cider vinegar and were subject to restricted calorie diet (RCD) for 12 weeks, while those in the control group followed the RCD. The subjects in the ACV group consumed 15 mL of apple cider vinegar with salad at lunch and 15 mL at dinner. Consuming salads with lunch and dinner was also suggested to the control group.

The subjects in both groups followed an RCD throughout the study. The RCD had 250 kcal/day lower than estimated energy requirement for each patient based on the Mifflin-St Jeor equation (Mifflin et al., 1990). Diets were designed to provide approximately 55% carbohydrate, 30% fat and, 15% protein. The study protocol did not change after the trial was commenced.

Table 3
Anthropometric parameters and body composition in ACV and Control groups.[1,a]

Variables	Study period			Changes during 12 weeks	*P* value *
	Baseline	Week 6	Week 12		
Body weight (kg)					
ACV	83.4 ± 16	81.3 ± 16	79.5 ± 15	−4 ± 2.5	0.001
Control	82 ± 14	80.5 ± 14	79.5 ± 14	−2.3 ± 1.6	0.01
P value**	0.82	0.45	0.52	0.01	
BMI (kg/m²)					
ACV	32 ± 5.3	31.1 ± 5.35	30.34 ± 5.15	−1.52 ± 0.9	0.001
Control	32.2 ± 4.5	31.7 ± 4.5	31.37 ± 4.65	−0.89 ± 0.6	0.001
P value	0.90	0.69	0.50	0.01	
BF (kg)					
ACV	38.18 ± 12.48	36.60 ± 12.25	34.54 ± 11.62	−1.57 ± 1.11	0.001
Control	37.98 ± 10.62	36.88 ± 10.15	35.56 ± 9.86	−1.1 ± 1.17	0.001
P value	0.95	0.93	0.77	0.20	
LBM (kg)					
ACV	44.77 ± 8.11	43.96 ± 8.32	43.85 ± 8.42	−0.91 ± 1.99	0.03
Control	43.80 ± 8.80	43.67 ± 9.09	43.99 ± 9.84	0.19 ± 1.81	0.51
P value	0.71	0.91	0.96	0.08	
Waist (cm)					
ACV	104.50 ± 9.70	101.63 ± 9.36	97.54 ± 8.35	−6.95 ± 3.38	0.001
Control	103.85 ± 7.25	101.75 ± 7.36	97.67 ± 7.25	−6.17 ± 4.21	0.001
P value	0.80	0.96	0.95	0.78	
Hip (cm)					
ACV	113.13 ± 8.31	110 ± 9.18	107.59 ± 8.84	−5.9 ± 3.71	0.001
Control	113.12 ± 12.07	111.62 ± 11.01	109.7 ± 10.25	−3.37 ± 2.49	0.001
P value	0.99	0.60	0.46	0.03	
WHR					
ACV	0.92 ± 0.05	0.92 ± 0.05	0.91 ± 0.05	−0.01 ± 0.03	0.15
Control	0.92 ± 0.07	0.91 ± 0.07	0.89 ± 0.05	−0.03 ± 0.04	0.002
P value	0.98	0.64	0.27	0.07	
VAI					
ACV: M	8.16 ± 1.66	–	4.75 ± 3.12	−3.6 ± 2.37	0.05
Control: M	4.50 ± 1.60	–	6.73 ± 5.85	1.98 ± 3.36	0.25
P value	0.09		0.48	0.02	
ACV: F	11.07 ± 6.10		8.83 ± 4.16	−3.6 ± 4.58	0.004
Control: F	4.36 ± 2.09	–	5.32 ± 3.64	1.4 ± 3.82	0.17
P value	0.23		0.09	0.001	

ACV: apple cider vinegar; BMI: body mass index; BF: body fat; LBM: lean body mass percent; WHR: waist to hip ratio; VAI: visceral adiposity index; M: male, F: female.
[1] All values are mean ± SD.
[a] $p < .05$ considered significant.
* A paired *t*-test for VAI& Repeated measures ANOVA for other variables.
** Analysis of covariance for changes during 12 weeks (adjusted for energy intake) & Student's *t*-test for variables.

2.3. Dietary intake assessment

A 3-day dietary recall was used to assess the dietary intakes of subjects (2 week days and 1 weekend) at baseline and six and twelfth weeks of the study. Diets of participants were analyzed by Nutritionist IV software (N Squared Computing, San Bruno, CA, USA).

2.4. ACV preparation and acetic acid content

ACV was purchased from traditional medicine stores in Tehran (Iran). These stores provide natural homemade ciders without industrial interference. The apples are prepared by washing and then cut into smaller pieces, then 1 kg of white vinegar was added for each 3 kg of apples and were put in containers and stored in warm place. Stirring of the containers occurred once a week and after 30 days the ACV was prepared.

High-performance liquid chromatography (HPLC) measurements were conducted, all tests were performed at the same laboratory (Shahid Beheshti University of nutrition and food science) (Morales, Gonzalez, & Troncoso, 1998). Blanks and acid standards were respectively used as positive and negative controls, in HPLC analysis. Duplicate samples were used in all the tests and none of the samples were blinded to the researchers. In preparation for HPLC analysis, samples from each brand were vortexed and centrifuged, and filtered HPLC was performed with a Waters chromatography system (Millipore) at a flow rate of 0.5 mL per minute and an injection valve set at 10 L with a variable ultraviolet wave length detector set at 210 nm. The separation was performed with a carbohydrate analysis column (3.9 300 mm) (Waters chromatography, Millipore). The mobile phase of all the samples was 0.1% H3PO4 adjusted to pH 1. Eventually, the sample with higher purity degree of 486 mg/100 mL acid acetic concentration was used.

2.5. Anthropometric assessment and body composition

Weight, hip and waist circumferences (WC) were assessed at baseline and the end of six and the end of 12 weeks of the study. Weight was measured to the nearest 0.1 kg, using a beam balance scale. A beam balance scale was used to measure the weight to the nearest 0.1 kg. Height was recorded by stadiometer to the nearest 0.1 cm. All readings were taken by light indoor clothing and without shoes. Then, BMI was calculated as weight in kilograms divided by height in meters squared. A plastic measuring tape was used for measuring the waist and hip circumferences by using the smallest girth below the rib cage and above

Table 4
Plasma concentrations of lipids and NPY in ACV and control groups.[1,a]

Biochemical variables	Study period		Changes during 12 weeks	*P* value*
	Baseline	Week 12		
TG (mg/dL)				
ACV	205.04 ± 22	146.95 ± 12	−58.1 ± 16	0.002
Control	142.55 ± 12	187.55 ± 28	45 ± 19.8	0.03
P value**	0.02	0.17	0.001	
TC (mg/dL)				
ACV	205 ± 27	202 ± 35	−5.1 ± 7.6	0.51
Control	208 ± 21	204 ± 20	−3.05 ± 6.6	0.65
P value	0.91	0.89	0.03	
LDL-C (mg/dL)				
ACV	135 ± 32	140 ± 35	3.5 ± 7	0.20
Control	147 ± 18	134 ± 31	−12 ± 9	0.82
P value	0.61	0.78	0.27	
HDL-C (mg/dL)				
ACV	31.44 ± 3	34.4 ± 5	2.95 ± 4	0.002
Control	31.41 ± 3	32.3 ± 4	0.68 ± 3	0.11
P value	0.97	0.19	0.04	
LDL-C/HDL-C				
ACV	4.3 ± 0.7	4.1 ± 1	−0.19 ± 0.9	0.63
Control	4.73 ± 0.7	4.2 ± 0.9	−0.57 ± 1	0.72
P value	0.47	0.49	0.78	
NPY (pg/mL)				
ACV	16.3 ± 3.9	17.5 ± 3.5	−1.18 ± 0.9	0.24
Control	17.3 ± 4.1	17 ± 2.6	−0.37 ± 1	0.72
P value	0.44	0.53	0.42	

ACV: apple cider vinegar; TG: triglyceride; LDL-C: low density lipoprotein-cholesterol; HDL-C: high density lipoprotein- cholesterol; NPY: Neuropeptide Y.
[1] All values are mean ± SD.
[a] $p < .05$ considered significant.
* A paired *t*-test.
** Analysis of covariance (adjusted for baseline TG and body fat changes) for changes during 12 weeks & Independent *t* test for variables.

the umbilicus (Hammond, 2008) and the largest girth between the waist and knees (Hammond, 2000). All readings were taken to the nearest 0.1 cm. Waist to hip ratio (WHR) was calculated as WC divided by hip girth. Total fat mass and lean body mass were assessed using bioelectric impedance analysis device (QuadScan 4000; Bodystat, Douglas, United Kingdom) at baseline and the end of 6 and 12 weeks of the study. Primary outcome of the study was anthropometric parameters and body composition. VAI is measured through the under formula which on WC (in cm), triglyceride (TG), and high-density lipoprotein (HDL-C) in mmol/L (Amato & Giordano, 2014).

$$Females: VAI = \left(\frac{WC}{36.58 + (1.89 \times BMI)}\right) \times \left(\frac{TG}{0.81}\right) \times \left(\frac{1.52}{HDL}\right)$$

$$Males: VAI = \left(\frac{WC}{39.68 + (1.88 \times BMI)}\right) \times \left(\frac{TG}{1.03}\right) \times \left(\frac{1.31}{HDL}\right)$$

2.6. Physical activity assessment

At baseline and the end of week 6 and 12, a valid Modifiable Activity Questionnaire (MAQ) (Kriska et al., 2006) was performed to assess the physical activity by calculating the metabolic equivalent (MET). The physical activity intensities were classified into low (MET < 600 min/wk), moderate (MET 600–1499 min/wk), and high (MET ≥ 1500 min/wk) (Sesso, Paffenbarger, & Lee, 2000).

2.7. Appetite assessment

Appetite was assessed by the Simplified Nutritional Appetite Questionnaire (SNAQ). SNAQ is a 4-item questionnaire and more recommended to be used for clinical purposes (Wilson et al., 2005). A 5-point scale (A = 1 to E = 5) was used for scoring each. The SNAQ items were as follow: #1, Appetite; #2, Feeling full; #3, Food tastes; #4, Feeling hunger and the sum of the 4 items scores constitutes the total SNAQ score and ranges from 4 to 20. The total score of 4 to 14 and 15 to 20 indicate low and normal appetite, respectively (Wilson et al., 2005).

2.8. Blood samples and biochemical assessment

At baseline and the end of week 12, 7 mL of blood was drown from the participant using EDTA-coated tubes after fasting for a 12- to 14-h. The plasma of samples was collected after centrifugation at 2000 rpm for 10 min and the specimens were divided into small aliquots and then were stored at -70 °C until further processing.

In the current study, secondary outcomes were plasma triglyceride, total cholesterol, HDL-C and low- density lipoprotein (LDL-C). Various colorimetric methods using commercial kits (Pars Azemoon, Tehran, Iran) and Selectra 2 Autoanalyzer (Vital Scientific, Spankeren, The Netherlands) were applied to assess the triglyceride, total cholesterol and HDL-C plasma concentrations. Intra-assay coefficients of variation (CV) for plasma triglyceride, total cholesterol and HDL-C were < 3%. Since the plasma triglyceride level of all participants was below 400 mg/dL, Friedwald equation was used to estimate the plasma LDL-C

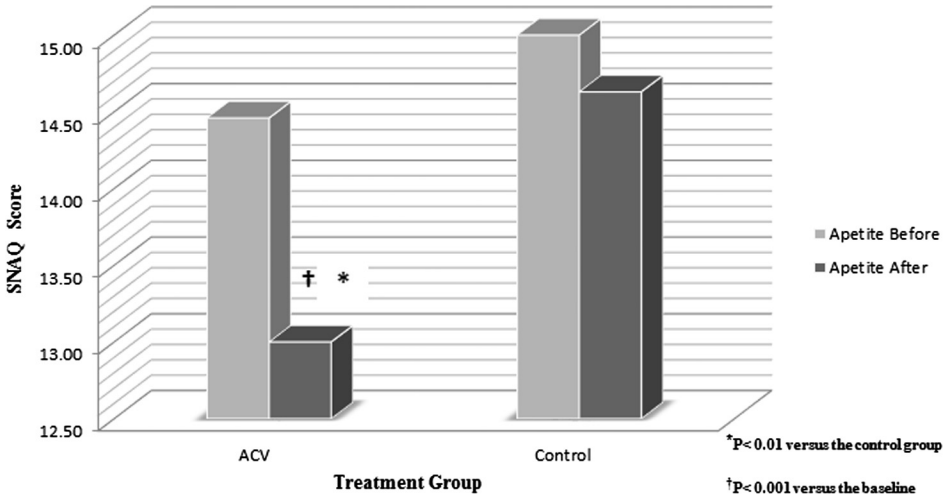

Fig. 2. The appetite scores in the ACV (with apple cider vinegar) and the control group (without vinegar); data are presented as mean ± SE during the study period. - SNAQ: Simplified Nutritional Appetite Questionnaire; ACV: apple cider vinegar.

(Friedewald, Levy, & Fredrickson, 1972). Plasma concentration of NPY was determined by enzyme-linked immunosorbent assay kit (Cusabio Biotech, Wuhan, China) and the intra-assay coefficient of variation (CV) was 7.7%. Samples were thawed at one time and all analyses were performed in duplicate.

2.9. Statistical analysis

Data is expressed as mean ± standard deviation (SD) or percentage (%). The Statistical Package for the Social Sciences for Windows version 21.0 was applied for statistical analysis (SPSS, Inc., Chicago, IL, USA). Intention-to-treat principle (ITT) and per-protocol analysis were applied for analyzing the data; the ITT results was only displayed because of the same outputs. Furthermore, ITT was completed with expectation maximization clustering algorithm. For comparing qualitative variables between the two groups, a χ^2 test was used. Since the distribution for all quantitative parameters was normal, based on Kolmogorov-Smirnov test, repeated measures ANOVA and paired *t*-test were used to compare parameters within groups. For comparing parameters between groups, Student's *t*-test was used and in order to adjust confounding factors (changes in body fat and energy intake), an analysis of covariance was also performed. The assumption of homogeneity of variance was tested using Levene's test. As dietary and anthropometric measurements were recorded 3 times throughout the study, analysis of variance for repeated measurements was applied to compare the effect of ACV at these time points. A p-value of ≤ 0.05 was considered as statistically significant.

3. Results

Of the 44 obese and overweight subjects eligible for this trial, 2 subjects in the ACV group (inability to cooperate or medical treatments) and 3 subjects in the control group (using medical treatments) were excluded (Fig. 1).

3.1. Baseline characteristics

No significant differences were found in the baseline characteristics of the subjects between the two groups (Table 1).

3.2. Dietary intakes and physical activity

The mean dietary energy intake reduced in both group following the trial**.** The ACV group showed significant reductions in energy intake during the study in comparison to baseline ($p = 0.01$); however, significant difference was not detected between the two groups at the week 6 or 12 (Table 2). The dietary fat intake was significantly reduced in both groups compared to baseline throughout the study ($p = 0.03$ in the ACV group and $p = 0.02$ in the control group). Furthermore, the intakes of saturated fatty acid (SFA) and mono-unsaturated fatty acid (MUFA) decreased significantly in the ACV group in comparison to baseline during the study ($p = 0.001$). SFA intake reduction was marginally significant in comparison with the control group by week 12 ($p = 0.05$). In addition, poly-unsaturated fatty acid (PUFA) intake was significantly reduced in the control group compared to baseline by week 12 ($p = 0.03$). Significant differences were not observed between the two groups with respect to energy intake as well as protein, carbohydrate, cholesterol, calcium and dietary fiber intake (Table 2). Changes in dietary intakes were adjusted for body fat changes. Also, no statistical significance was found in regards to the physical activity of subject in both groups.

3.3. Effects on anthropometric measurements

BMI, body fat (BF), waist and Hip circumference reduced significantly in ACV and the control group in comparison to baseline ($p = 0.001$). Moreover, body weight and WHR were also decreased significantly in the control group compared to baseline ($p = 0.0$, $p = 0.002$; respectively). Lean body mass (LBM) was also significantly reduced in the ACV group in comparison to baseline ($p = 0.03$). Furthermore, WHR significantly decreased in the control group in comparison to baseline ($P = 0.002$). Body weight, BMI and hip girth were significantly reduced in the ACV group in comparison to the control group during the 12 weeks ($p < 0.05$).VAI was significantly decreased in the ACV group compared to the control group in both sexes (in male: $p = 0.02$; in female: $p = 0.001$); however VAI was also significantly decreased in the female of ACV group compared to baseline by week 12 ($p = 0.004$) (Table 3). Anthropometric measurements were adjusted for energy intake.

3.4. Effects on plasma lipids and NPY

Plasma TG concentrations reduced in the ACV group by week 12 was observed in comparison to baseline and this reduction was also significant in comparison to control group ($p = 0.001$), also there was significant increases in TG levels in the control group compared to baseline ($p = 0.035$). HDL-C level was also significantly increased in the ACV compared to the control group ($p = .0049$). Furthermore, total cholesterol (TC) was also significantly decreased in the ACV group compared to the baseline. Moreover, the changes observed in plasma concentrations of LDL-C, LDL-C/HDL-C and NPY were not statistically significant during the study period (Table 4). Lipid profiles were adjusted for baseline TG and body fat changes.

3.5. Effects on appetite

At the end of the study, the SNAQ score reduced significantly in the ACV group in comparison to the control group ($p = 0.04$). Appetite reduction was also demonstrated in ACV group by week 12 ($p = 0.001$) (Fig. 2).

4. Discussion

In the present study, oral administration of ACV along with RCD significantly decreased body weight, BMI, hip circumference and Visceral Adiposity Index (VAI) in comparison to the control. No clinical trials have investigated the effects of ACV and RCD together on anthropometric parameters in overweight or obese subjects. However, few animal studies (Lee et al., 2013; Lim et al., 2009; Ok et al., 2013; Seo et al., 2014) and clinical trials (Kondo et al., 2009; Park et al., 2014) have been performed investigating the effects of vinegar consumption on overweight or obesity. In accordance with our study, Kondo et al. showed that apple vinegar consumption (15 or 30 mL/day) for 12 weeks reduced body weight, BMI, hip circumference, and WHR (Kondo et al., 2009). In addition, some animal studies indicated that vinegar intake has a favorable effect on controlling body weight (Lim et al., 2009; Ok et al., 2013; Seo et al., 2014). In contrast, Park reported that daily consumption of pomegranate vinegar for 8 weeks did not significantly reduce body weight and BMI in overweight or obese subjects (Park et al., 2014). Also, Lee et al. showed that tomato vinegar had no significant effects on body weight in comparison to the control group in obese rats (Lee et al., 2013). Although, inconsistencies somehow can be related to the different type of vinegar and the study design. In the present study, regarding the beneficial effect of ACV on anthropometric parameters and VAI as a gender dependent mathematical model, reflecting visceral adiposity (Al-Kuraishy & Al-Gareeb, 2016); it seems that ACV may play a synergetic role along with RCD on weight reduction in obesity.

Several mechanisms have been suggested for the beneficial effect of vinegar consumption on body weight. The first mechanism is a hunger reduction and consequently a decrease in food intake (Petsiou, Mitrou, Raptis, & Dimitriadis, 2014). Accordingly, at the end of our study, SNAQ scores, as an appetite indicator, reduced significantly in the ACV

group in comparison to the control group, while no statistical significant was found in the control group. Ostman et al. indicated that the effect of vinegar consumption on the satiety score was directly related to acetic acid content of the vinegar (Östman, Granfeldt, Persson, & Björck, 2005). In our study, ACV consumption had no effect on plasma NPY concentration, as an appetite-stimulating neuropeptide. Therefore, it seems that appetite control by ACV is not related to plasma NPY. The second mechanism of the effect of vinegar consumption on body weight is an increase in energy expenditure (Petsiou et al., 2014). However, the thermic effect or dietary induced thermogenesis of ACV consumption was not investigated in our study but in accordance with the level of restricted calorie intake (−289 calorie for 12 weeks), approximately half a kilogram weight loss more than the expected amount for this duration may be related to the thermic effect of ACV.

In the present study, BF and waist circumference significantly decreased in both groups, but no significant reductions in these variables between the two groups were found. In addition, WHR was significantly decreased in the control group but this was not significantly different between the two groups. Based on the currently available literature, no previous study investigated the effect of ACV and RCD together on BF and waist circumference in overweight or obese subjects. However, Kondo et al. demonstrated that apple vinegar consumption (15 or 30 mL/day) for the period of 12 weeks significantly reduced waist circumference in comparison to the control (Kondo et al., 2009). Also, Park et al. reported that daily consumption of pomegranate vinegar for 8 weeks significantly reduced total fat mass in overweight or obese subjects compared to the control group, but pomegranate vinegar consumption had no effect on lean tissue (Park et al., 2014).

In current study, plasma TG level reduced significantly in the ACV group by week 12 in comparison to the placebo group. In accordance with this result, Kondo et al. revealed that apple vinegar ingestion significantly reduced serum triglyceride (Kondo et al., 2009). In addition, some animal studies indicated that vinegar consumption had a hypotriglyceridemic effect (Ok et al., 2013; Seo et al., 2014). The mechanism of the effect of vinegar consumption on serum triglyceride may be attributed to reduction in the formation of triglycerides in the liver (Fushimi et al., 2006) due to a reduction in body weight. However, Park et al. reported that serum triglyceride of overweight women remained unchanged after consumption of pomegranate vinegar (Park et al., 2014). Moreover, HDL-C level significantly increased in ACV compared to the control group. Previous studies implied that the HDL-C enhancing effect of ACV may be related to its ability to decreased the glycemic index of high glycemic index foods (Petsiou et al., 2014). In this study, no significant changes in plasma TC and LDL-C levels were observed after apple cider vinegar consumption. However, findings of other studies on lipid parameters have been contradictory (Kondo et al., 2009; Ok et al., 2013; Park et al., 2014). This may be due to differences in study design, baseline lipid parameters, duration, amount and type of consumed vinegar. So according to the contradictory results and scarce human clinical trials (Beheshti et al., 2012; Panetta, Jonk, & Shapiro, 2013), further research are needed in this field to confirm our results.

Some recognized limitations of this study should be addressed, including the design not being a double-blinded placebo-controlled study due to odor of the ACV, so an odor masking method could have been used. However, the treatment was assigned randomly to the groups. Moreover, capsule administration might have caused taste-blinding and limited the full physiological effect of vinegar. Since clinical trials have been rarely conducted in the field, the design used in the present study is one of its strengths. On the other hand, gold standard technique was not used for measuring body composition; however bioelectrical impedance analysis has a good validity and reliability. Another point that should be addressed is insufficient sample size (which made it impossible to perform the longitudinal data analysis) and also the higher female participants make extrapolation difficult; so a larger scale study is required to be conducted for more representable data. Another limitation is attributed to the lack of polyphenol analysis. Other strengths which should be addressed are the use of 3-day food records and the long follow-up period.

5. Conclusion

This study indicates that apple cider vinegar consumption along with restricted calorie diet can decrease appetite, body weight, BMI, hip circumference, VAI, plasma triglyceride, total cholesterol concentration and also increase HDL-C level in overweight or obese subjects. An implication of this is the possibility that ACV could be used as an adjunctive therapy in concomitant with RCD or other standard way of weight management therapy through appetite controlling or increasing thermic effect of food component. Taken together, these results suggest that larger randomized clinical trial along with evaluation of thermic effect of ACV and another anorexigenic neurotransmitters or gut peptides is needed for getting more elucidative results.

Conflict of interest

The authors declare that they have no conflict of interest.

Author Contribution

SKH and AS had full access to all of the data in the study and took responsibility for the integrity of the data and the accuracy of data analysis. NH, ZA and AS conceived and designed the study and provided administrative support. SKH, NH, ZA, and AS conducted the study. SKH and AS wrote the manuscript

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