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Original research

Comparison of dietary patterns, food groups, nutrients intake, cardio-metabolic biomarkers, and liver enzymes in successful and unsuccessful weight loss maintainers

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ABSTRACT

Purpose: Compare dietary patterns, food groups, nutrients intake, cardio-metabolic risk factors, and liver enzymes between female weight loss maintainers and regainers.

Methods: The present study was conducted using a case-control design on 263 participants. Cases and controls were matched regarding sex, ethnicity, and family history of obesity. Three 24-h dietary recalls were used to extract the usual dietary intake and major dietary patterns; the three-factor eating questionnaire was administered to evaluate the dietary habits; and blood sampling was performed to evaluate fasting blood sugar, lipid profile, and liver enzymes.

Results: In total, three major dietary patterns were identified: Mediterranean-like dietary pattern, high-fat-high-carbohydrate (HFHC) dietary pattern, and Iranian traditional dietary pattern. Higher adherence to the Mediterranean-like and Iranian traditional dietary patterns increased the odds of success in weight loss maintenance (P-value < 0.001 and $p < 0.001$, respectively). The HFHC dietary pattern was associated with lower success in weight loss (P-value < 0.001). Maintainers had lower daily energy and carbohydrate intake (P-value < 0.001), but not lower fiber, calcium and folate (P-value > 0.05); even in the maintainers the calories percent from protein was higher than regainers (P-value < 0.001). Longer duration of weight loss period (P-value < 0.001), and combination of diet and exercise method in weight loss (P-value $= 0.028$) were more frequent and attempts for weight loss (P-value < 0.001) was less frequent among maintainers compared to regainers. Participants with successful weight loss had significantly lower fasting blood sugar and gamma-glutamyltransferase levels after adjusted for confounding factors (P-value < 0.001 and $p = 0.004$, respectively).

Conclusion: Results indicated a higher healthy dietary patterns and lower adherence to unhealthy dietary patterns and different intake of food groups and nutrients in maintainers compared to regainers.

1. Introduction

Obesity is a public health problem due to the worldwide increasing trend in body mass index (BMI) (Chooi et al., 2019). The prevalence of overweight and obesity has been doubled since 1980 and currently about one-third of the world population is affected by this condition (Collaborators, 2017). Thousands of studies suggested different ways to achieve lower body weight such as change in lifestyle, interventions with a dietary component like intermittent or continuous energy restriction, and an increase in physical activity in combination with moderate dieting (Barte et al., 2010; Harvie et al., 2011; Lewis et al., 1976). Based on evidence, it seems that losses of 5–10% of body weight are achievable by a change in lifestyle (Group, 2010). However, long-term weight loss maintenance is a well-known challenge, and there is scarce evidence in this regard (Thomas et al., 2014).

Reports suggested that within five years from weight loss, most people regain their initial weight (Brownell and Jeffery, 1987). In contrast, in some longitudinal studies, more than half of the adults who had lost 10% of their body weight maintained this weight loss over the following years (McGuire et al., 1999; Weiss et al., 2007). International

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Weight Control registries suggested several factors that may be involved in the successful maintenance of reduced weight, including adherence to a restrictive dietary plan (Phelan et al., 2006), change in the macronutrient composition of the diet, physical activity, limited fast foods (Phelan et al., 2006), limited variety of food groups (Raynor et al., 2005), high protein intake (Karfopoulou et al., 2017; Santos et al., 2017), the rate of weight loss (Pi-Sunyer et al., 1998), cognitive and behavioral care (Voils et al., 2017), moderate-fat-high-fiber diet (Hjorth et al., 2017), and replacing beverages with water (Madjd et al., 2018). However, several studies failed to design an effective program for weight loss maintenance (Keogh et al., 2014; Lowe et al., 2014; Pekkarinen et al., 2015; Purcell et al., 2014). Thus, considering equivocal results and the limited number of studies investigating dietary intakes in weight loss maintenance, there is a need for more research in this area to recommend a specific dietary pattern.

A helpful approach to finding effective strategies for maintaining weight loss is inspecting the change in the lifestyle of successful maintainers. The majority of studies focused on dietary habits and eating practices, such as change in energy restriction methods (Keogh et al., 2014), meal replacement (Lowe et al., 2014), and behavioral counseling (Voils et al., 2017), but few evaluated the difference in macro- and micronutrients, food groups, or whole-dietary patterns between successful and unsuccessful weight loss maintainers. Raynor et al. (2011) indicated a low-energy-dense diet, characterized by a higher intake of vegetables and whole grains in maintainers. Also, the study by Karfopoulou et al. (2017) suggested a higher intake of salty snacks, alcohol, and soft drink, and lower intake of protein in male regainers compared to maintainers. In addition, male maintainers are more likely to adhere to the healthy dietary pattern, characterized by a high intake of unprocessed cereal, fruit, vegetables, olive oil, and low-fat dairy. However, this association was not found in women.

It is known that body fat increases the risk of cardio-metabolic conditions (Garcia et al., 2016; Lu et al., 2016). Although obesity management improves the cardiometabolic risk profile (van Dammen et al., 2018), the effects of weight regain and maintenance remain inconsistent (Dandanell et al., 2017; Petersmarck et al., 1999). Evidence suggests the negative impact of cycling weight loss on body composition, resulting in a greater fat mass (Beavers et al., 2011). Thus, the effect of long-term weight maintenance and regain should be clarified. Moreover, adiposity may predispose individuals to liver disease (Riley et al., 2007), and obesity management is a key driver of improvement in liver enzymes (Straznicky et al., 2012). Nevertheless, the effect of weight maintenance on liver health has been elucidated.

Therefore, the purpose of the present study was to compare dietary intakes in terms of nutrients, food groups, and dietary patterns, between weight loss maintainers and regainers. In addition, this study aimed to determine the association between success in weight loss and cardio-metabolic risk factors and liver enzymes in the year following intentional weight loss in women.

2. Materials and methods

2.1. Participants

The present study was conducted on women using a case-control design on 263 participants from hair salons and sport clubs of Urmia, Iran, in 2018. The simple sampling was used to select subjects consecutively based on inclusion, and exclusion criteria. The case group included 137 women with a history of successful weight loss maintenance (SWL; lost at least 10% of weight and maintained it for at least one year) and the control group included 126 women who did not succeed in maintaining their weight loss (UWL; lost at least 10% of weight and regained weight to more than 95% of the maximum weight) (Fig. 1). The sample size was calculated using the hunger factor in a previous study (Hume et al., 2015), with the power of 90% and 95% confidence interval using the following formula:

$$n = \frac{(Z_{1-\alpha/2} + Z_{1-\beta})^2 \times (S_1^2 + S_1^2)}{(\mu_1 + \mu_2)^2}$$

The participants were enrolled in the study if they met the following inclusion criteria: adults aged 18–65 years, BMI $\geq 25\ kg/m^2$ before initiating weight loss, and a history of successful (cases) or unsuccessful (controls) 10% weight loss maintenance at least one year after weight loss. Individuals with a history of bariatric surgery, taking medications or drugs that would affect weight, other medical procedures impacting weight (such as cryolipolysis, lipovaser, and cavitation), pregnancy in the last year, menopause, or chronic diseases (such as cardiovascular disease, cancer, diabetes, hepatic or renal disease, and neurological disorders) were excluded from the study. Cases and controls were matched regarding sex, ethnicity, and family history of obesity. The method of the study was approved by Ethics Committee at Urmia University of Medical Sciences (IR.umsu.Rec.1396.370), and the consent form was completed by participants following the description of the method and purpose of the research.

2.2. Experimental design

2.2.1. Demographic characteristics and physical activity

General information, including participants' age, ethnicity, marital status, education level, duration of weight loss maintenance, time to lose 10% of the initial weight, maximum experienced weight, weight loss rate, family history of obesity, number of previous attempts to lose weight, weight fluctuations in the last year, and history of childhood obesity were collected using a demographic questionnaire. Also, the Metabolic Equivalent of Task (MET) questionnaire was administered to determine the physical activity level of participants (Craig et al., 2003). The physical activity score is represented as MET.hr/day.

2.2.2. Anthropometric measurements

A digital scale (Seca, France) with the precision of 100 g was employed to measure weight with minimum clothes and without shoes. Height was measured using a stadiometer (Seca, France) with the precision of 0.1 cm in a standing position next to a wall, without shoes, and with relaxed shoulders. Then BMI was computed by dividing the weight (kg) by the square of height (m^2).

2.2.3. Blood sampling and biochemical assessment

In total, 101 participants (59 SWL and 42 UWL) agreed to cooperate for blood sampling. Five mL of blood sample was taken after 10–12 h of fasting between 7 and 9 a.m. To separate the serum, the blood samples were centrifuged at room temperature at 4000 rpm for 10 min and the isolated serum was stored at −80 °C until performing the biochemical tests. Fasting blood glucose (FBS) and triglyceride (TG) were measured using the colorimetric enzymatic method (Pars Azmoon kit, Pars Azmoon Co., Tehran, Iran). Total cholesterol, low-density lipoprotein (LDL), and high-density lipoprotein (HDL) were measured using the enzymatic photometric method (Pars Azmoon kit, Pars Azmoon Co., Tehran, Iran). Finally, serum concentrations of liver enzymes (AST, aspartate transaminase; ALT, alanine transaminase; ALP, alkaline phosphatase; GGT, gamma-glutamyltransferase) were assessed using Pars Azmoon test kits (Pars Azmoon Co., Tehran, Iran).

2.2.4. Dietary intake and dietary habit assessment

Three 24-h dietary recalls were used to assess the usual dietary intake of the participants. Previous studies confirmed the reliability and validity of the questionnaire for the Iranian population (Abdollahi et al., 2016). The participants were asked to recall the amount of every food item they consumed in two non-consecutive days (in-person interview) and one weekend day of the week (telephone interview). Then, the data were entered into the Nutritionist IV software (1997, First DataBank Inc., San Bruno, CA) and the mean daily intake of each food item (as g/day) and nutrients content were estimated. In addition, the

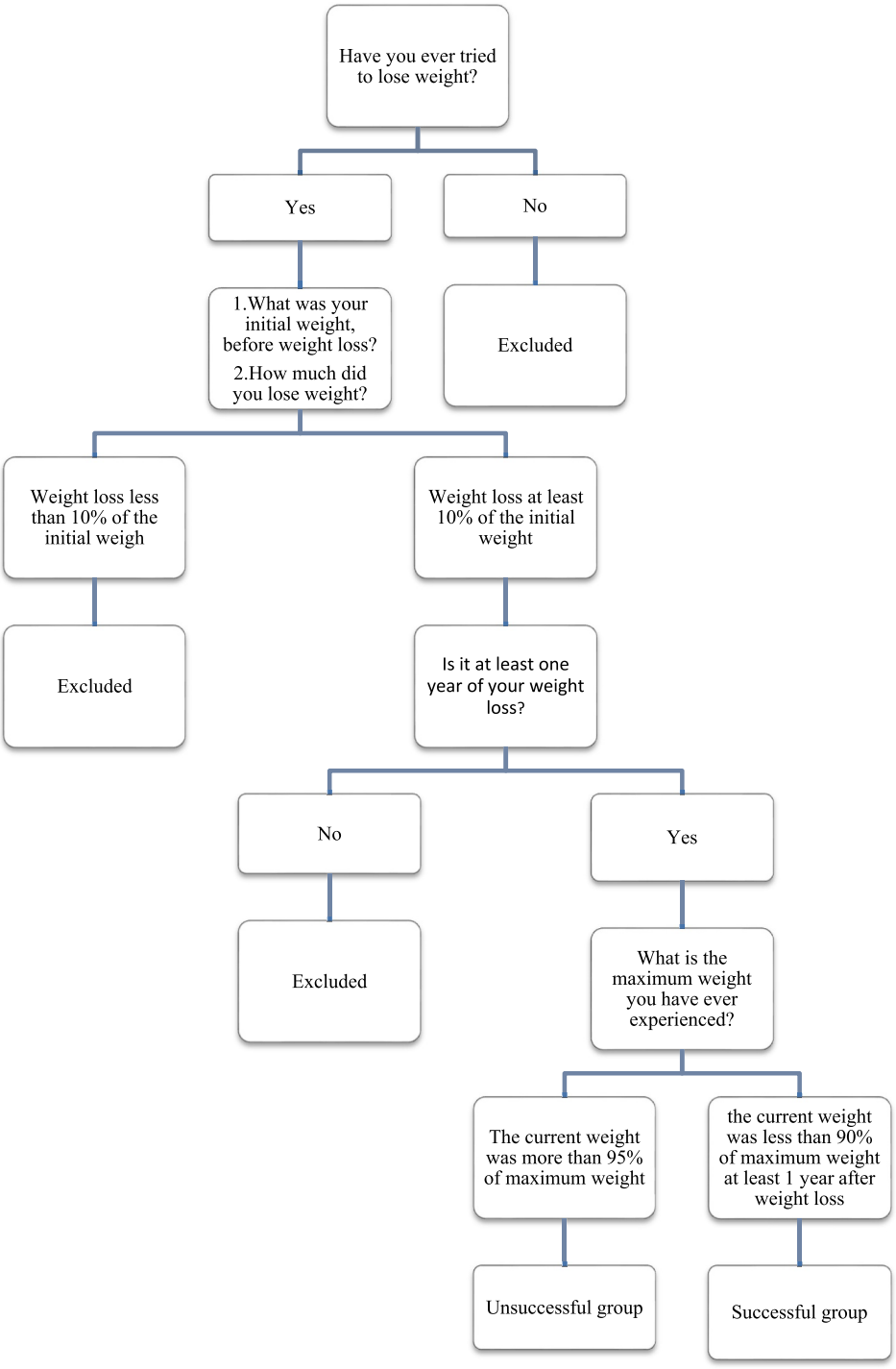

Fig. 1. Sampling flowchart.

three-factor eating questionnaire (Dietary Restraint, Disinhibition and Hunger) was administered to evaluate the dietary habits of participants (Bond et al., 2001). This questionnaire consists of 50 item evaluating different aspects of psychological dietary habits. Questions including meals with concurrent activities, meals eaten with family, recording food intake, recording weight loss target, reducing portion size, reducing serving size, consumption of soft drinks and sweets, duration of watching the television, duration of using the Internet, reading food labels, time of eating lunch and dinner, time interval between dinner and sleep, and desire to eat sweet foods after meals were added to the three-factor eating questionnaire. The validity and reliability of the new questionnaire were confirmed by 10 expert nutritionists.

2.3. Statistical analyses

Quantitative and qualitative data are presented as mean ± SD and frequency (%), respectively. The Kolmogorov-Smirnov test was run to assess the normality of the quantitative variables. The independent T-test or Mann-Whitney *U* test was used to evaluate the association between success in weight loss maintenance and quantitative variables. Also, the Chi-squared test was run to investigate the significance of the relationship between success in weight loss maintenance and qualitative variables. Principle component analysis (PCA) with varimax rotation was employed to identify major dietary patterns. To this end, food items were first categorized into 23 groups according to their content

Table 1
Relationship between qualitative demographic characteristics and success in weight loss maintenance.

Variable [a]		SWL	UWL	P-value [b]
Education level	≤12 years	28 (20.4)	49 (38.9)	0.004
	13–16 years	83 (60.6)	57 (45.2)	
	≥16 years	26 (19.0)	20 (15.9)	
Ethnicity	Turk	115 (83.9)	101 (80.2)	0.185
	Kurd	15 (10.9)	22 (17.5)	
	Fars	7 (5.1)	3 (2.4)	
Marital status	Single/ divorced/ widow	74 (54.0)	23 (18.3)	< 0.001
	Married	63 (46.0)	103 (81.7)	
Weight loss method	Diet	17 (12.5)	23 (18.7)	0.028
	Exercise	6 (4.4)	16 (13.0)	
	Both	112 (82.4)	83 (67.5)	
	None	1 (0.7)	1 (0.8)	
Family history of obesity	Yes	110 (80.3)	109 (86.5)	0.177
	No	27 (19.7)	17 (13.5)	
History of overweight	Before school	4 (2.9)	18 (14.3)	< 0.001
	During school	46 (33.6)	21 (16.7)	
	Recently	84 (61.3)	87 (69.0)	
	All	3 (2.2)	0 (0.0)	
Frequency of attempts for weight loss	1	50 (36.5)	16 (12.7)	< 0.001
	2–3	51 (37.2)	38 (30.2)	
	4	36 (26.3)	72 (57.1)	
Weight change in last year	Reduced	57 (41.6)	5 (4.0)	< 0.001
	Increased	7 (5.1)	59 (46.8)	
	No change	42 (30.7)	1 (0.8)	
	Both reduce and increase	31 (22.6)	61 (48.4)	

SWL, successful weight loss; UWL, unsuccessful weight loss.
[a] Presented as frequency (%).
[b] Calculated using chi-square.

similarity based on the previous studies (Table 2) (Esmaillzadeh et al., 2007). Then, these food groups entered PCA and, according to the scree plot, factors with eigenvalues ≥1.99 were considered as major dietary patterns. The total score of participants in terms of adherence to a dietary pattern was calculated using the loading factor of different food groups (Table 2). Loading factors < 0.2 are not shown in the table for simplicity. Logistic regression was also used to calculate the odds ratio (OR) in the association between dietary patterns and success in weight loss maintenance. Ultimately, four models were developed to control for the effects of confounding variables on the relationship between the independent variable (dietary patterns) and the dependent variable (success in weight loss maintenance). In Model 1, the relationship was adjusted in terms of age, education level, physical activity, and marital status. In the second model, the duration of maintaining weight loss, time to reach 10% weight loss, weight loss method, overweight history, number of previous attempts to lose weight, and weight fluctuations in the last year were added to the previous variables. In the third model, food habits, including the meals with concurrent activities, meals eaten with family, recording food intake, recording weight loss target, reducing portion size, reducing serving size, consumption of soft drinks and sweets, duration of watching the television, duration of using the Internet, reading food labels, time of eating lunch and dinner, time interval between dinner and sleep, and desire to eat sweet foods after meals were added to the former variables. Eventually, energy intake was added to previous variables in Model 4. Data were analyzed using SPSS software version 22 (IBM Corp. IBM SPSS Statistics for Windows, Armonk, NY), and p-values < 0.05 were considered as statistically significant.

3. Results

3.1. Population characteristics

In total, 263 individuals participated in the present study. Fig. 2 shows the differences in quantitative demographic variables according to the case (SWL) and control (UWL) groups. In addition, the distribution of qualitative variables has been presented in Table 1. Based on the results, participants in the SWL had a significantly lower age ($p < 0.001$). In contrast, those in the UWL had a lower physical

Table 2
Food groups and factor-loading matrix for major dietary patterns.[a].

Food groups	Food items	Dietary Patterns		
		1	2	3
Refined grains	White bread (lavash, toast, baguette, sangak), noodles, pasta, white flour, starch, cornflakes, corn, boiled potato, rice	−0.481	0.315	−2.40
Whole grains	Whole bread (barbari), milled barley, wheat germ, bulgur, bean, chickpea, split pea, lentil, broad bean, mung			0.542
Soybean	Soybean			0.257
Omega-3 sources	Fish, tuna, walnut	0.361		
Red meat and organs	Beef, lamb, ground meat	−0.667		
Poultry	Chicken	0.328	0.234	0.481
Eggs	Eggs	0.474		
Fruit juices	Fruit (apple, orange, cantaloupe, …) juices		0.399	
Fruits	Watermelon, melon, apple, apricot, fig, nectarine, peach, pear, Citrus fruit, date, kiwi, pomegranate, Persimmon, prunes, grape, strawberry, banana, berries, grapefruit, cherries, other fruits			0.537
Vegetables	Spinach, lettuce, mixed vegetable, stew vegetables, local vegetables, kinds of cabbage, celery, carrots, pumpkin, Eggplant, green squash, pepper, cucumber, garlic, tomato, onion, mushroom, green peas, green beans, turnip, and other vegetables	0.340	−0.202	0.237
Omega-6 sources	All oils except olive and canola oil, pistachio, hazelnut, sunflower seeds	−0.471	0.491	
MUFA sources	Olive, olive oil, almonds, peanuts	0.500		
Low fat dairies	Skim or low-fat milk, low-fat yogurt, curd	0.323	−0.236	0.471
High fat dairies	High-fat milk, whole milk, chocolate milk, high-fat yogurt, cream yogurt, cream cheese, other cheeses, ice cream		−0.260	
Dairy fats	Cream, butter, ghee	−0.427		0.321
Dried fruits	Dried figs, raisin, dried mulberries, dates and other dried fruits	0.272	0.287	
Pickle	Pickles, brine		0.425	
Snack	Potato chips, corn puffs, crackers, popcorn		0.301	−0.325
Fast foods	Hamburger, sausages		0.334	−0.375
Coffee	Coffee	0.310		
Sweets and sugars	Biscuit, cakes, cookies, confections, pastries, sugars, sugar cube, candies, gaz (an Iranian confectionery made of sugar, nuts, and tamarisk), chocolate, jam, jelly	−0.280	0.433	−0.282
Honey	Honey		0.494	0.490
Soft drinks	Soda, soft drinks		0.618	

[a] Values < 0.20 were excluded for simplicity.

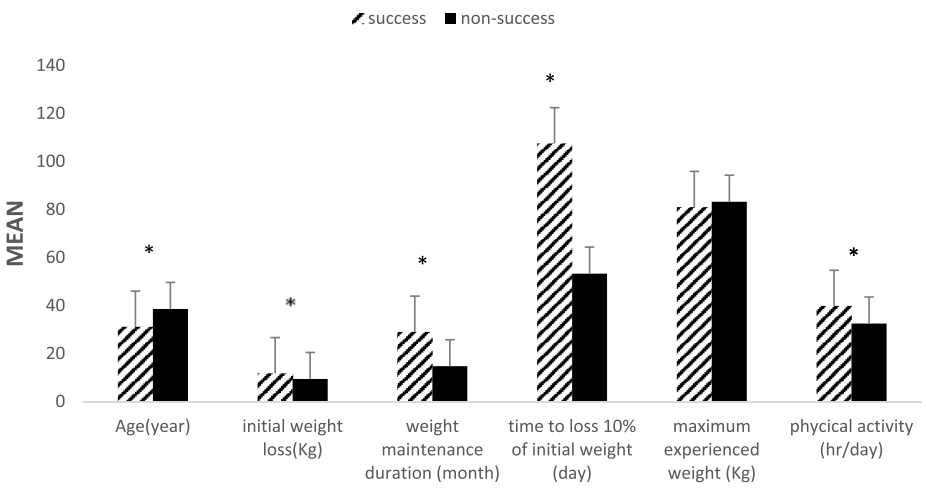

Fig. 2. Relationship between quantitative demographic characteristics and success in weight loss maintenance. Values are presented as mean ± SD. Significant differences ($P < 0.05$) are indicated by asterisks (*). The significance of the differences was evaluated using the independent T-test or Mann-Whitney *U* test.

activity ($p < 0.001$), initial weight loss ($p < 0.001$), duration of weight loss maintenance ($p < 0.001$), and time to reach 10% weight loss ($p < 0.001$). Furthermore, there was a significant association between success in weight loss maintenance and education level ($p = 0.004$), marital status ($p < 0.001$), weight loss method ($p = 0.028$), history of overweight ($p < 0.001$), frequency of weight loss ($p < 0.001$), and weight fluctuations in the last year ($p < 0.001$). However, no association was observed between success in weight loss maintenance and maximum experienced weight ($p = 0.086$).

3.2. Association between major dietary patterns and success in weight loss

In the present study, three major dietary patterns were identified using PCA (Table 2): Dietary Pattern 1 (DP1, Mediterranean-like dietary pattern, characterized by high intakes of MUFA sources, eggs, omega-3 sources, vegetables, poultry, low-fat dairies, coffee, and dried fruits, and low intakes of red meat, refined grains, omega-6 sources, dairy fat, sweets, and sugars), Dietary Pattern 2 (DP2, high-fat-high-carbohydrate dietary pattern, characterized by high intakes of soft drinks, honey, sweets and sugars, omega-6 sources, pickles, fruit juices, fast foods, refined grains, snacks, dried fruits, and poultry, and low intakes of vegetables, low-fat dairies, and high-fat dairies), and Dietary Pattern 3 (DP3, Iranian traditional dietary pattern, characterized by high intakes of whole grains, fruits, honey, poultry, low-fat dairies, dairy fats, soybean, and vegetables, and low intake of fast foods, snacks, sweets and sugars, and refined grains). The identified dietary patterns contributed to 27.92% of the population variance.

The association between success in weight loss maintenance and major dietary patterns has been provided in Table 3. According to the logistic regression, higher adherence to the Mediterranean-like and Iranian traditional dietary patterns increased the odds of success in weight loss maintenance (OR = 2.32, 95% CI = 1.70–3.17, p-value < 0.001, and OR = 1.89, 95% CI = 1.39–2.57, $p < 0.001$, respectively). For the Mediterranean-like dietary pattern, the significance of the relationship was not changed upon adjustment for the effect of age, education level, physical activity, marital status, the duration of maintaining weight loss, time to reach 10% weight loss, weight loss method, overweight history, number of previous attempts to lose weight, weight fluctuations in the last year, meals with concurrent activities, meals eaten with the family, recording food intake, recording weight loss target, reducing portion size, reducing serving size, consumption of soft drinks and sweets, duration of watching the television, duration of using the Internet, reading food labels, time of eating lunch and dinner, time interval between dinner and sleep, desire to eat sweet foods after meals, and energy intake in Models 1 to 4 (OR = 3.62, 95% CI = 1.72–7.60, p-value = 0.001). For the Iranian traditional dietary pattern, adjusting for confounding variables in Models 1 and 2 reduced the OR, and the association was not significant in Model 2 (OR = 1.58, 95% CI = 0.96–2.58, p = 0.069). Nevertheless, in Models 3 and 4, the OR increased again and was statistically significant.

Results indicated that the high-fat-high-carbohydrate dietary pattern was associated with lower success in weight loss in the crude model (OR = 0.53, 95% CI = 0.39–0.71, p-value < 0.001). This association remained significant after adjusting for the effect of confounding variables in Models 1, 2, 3, and 4 (OR = 0.48, 95% CI = 0.25–0.89, p-value = 0.020).

Table 3
Logistic regression for the association between major dietary patterns and success in weight loss maintenance.

		OR	95% CI	P-value
DP1	Crude model	2.32	1.70–3.17	< 0.001
	Model 1 [a]	2.26	1.54–3.30	< 0.001
	Model 2 [b]	2.28	1.45–3.57	< 0.001
	Model 3 [c]	3.22	1.59–6.50	0.001
	Model 4 [d]	3.62	1.72–7.60	0.001
DP2	Crude model	0.53	0.39–0.71	< 0.001
	Model 1 [a]	0.46	0.32–0.65	< 0.001
	Model 2 [b]	0.45	0.29–0.71	0.001
	Model 3 [c]	0.44	0.25–0.76	0.003
	Model 4 [d]	0.48	0.25–0.89	0.020
DP3	Crude model	1.89	1.39–2.57	< 0.001
	Model 1 [a]	1.69	1.16–2.46	0.006
	Model 2 [b]	1.58	0.96–2.58	0.069
	Model 3 [c]	1.87	1.03–3.38	0.038
	Model 4 [d]	3.19	1.58–6.45	0.001

SWL, successful weight loss; UWL, unsuccessful weight loss; DP, dietary pattern; OR, odds ratio; CI, confidence interval.

[a] Adjusted for age, education level, physical activity, and marital status.

[b] Adjusted for variables in model 1 and the duration of maintaining weight loss, time to reach 10% weight loss, weight loss method, overweight history, frequency of weight loss in the past, and weight fluctuations in last year.

[c] Adjusted for variables in model 2 and meals with concurrent activities, meals eaten with family, recording food intake, recording weight loss target, reducing portion size, reducing serving size, consumption of soft drinks and sweets, duration of watching TV, duration of using internet, reading food labels, time of eating lunch and dinner, time interval between dinner and sleep, desire to eat sweet foods after meals.

[d] Adjusted for variables in model 3 and energy intake.

Table 4
Relationship between nutrient intake and success in weight loss maintenance.

Nutrients [a]	SWL	UWL	P-value [b]
Energy (kcal)	1580.88 ± 405.08	1830.74 ± 351.63	< 0.001
Carbohydrate (gr)	196.98 ± 57.77 46.70 ± 7.22	233.81 ± 47.52 49.41 ± 4.93	< 0.001 < 0.001
Carbohydrate (%)			
Protein (gr)	85.02 ± 32.54 21.29 ± 5/90	84.94 ± 24.56 18.67 ± 4.96	0.576 < 0.001
Protein (%)			
Fat (gr)	61.27 ± 18.01 32.00 ± 5.68	68.78 ± 16.33 31.92 ± 5.07	0.001 0.902
Fat (%)			
SFA (gr)	14.84 ± 4.86	17.16 ± 4.96	< 0.001
PUFA (gr)	12.04 ± 4.11	14.15 ± 4.61	< 0.001
Trans fatty acids (gr)	0.93 ± 0.33	1.08 ± 0.35	< 0.001
Cholesterol (mg)	221.03 ± 115.12	209.37 ± 99.98	0.587
Fiber (gr)	26.38 ± 8.85	26.78 ± 8.16	0.707
Fe (mg)	13.31 ± 4.01	14.69 ± 3.40	0.003
Calcium (mg)	786.86 ± 282.68	744.07 ± 203.47	0.175
Folate (μg)	416.03 ± 155.81	423.60 ± 121.16	0.663
Sodium (mg)	1377.18 ± 541.54	1753.52 ± 472.32	< 0.001

Gr, gram; mg, milligram; μg, microgram; SFA, saturated fatty acids; PUFA, polyunsaturated fatty acids; SWL, successful weight loss; UWL, unsuccessful weight loss.
[a] Presented as mean ± SD.
[b] Calculated using independent sample *t*-test or Mann-Whitney *U* test.

3.3. Association between nutrient and food group intake and success in weight loss

Table 4 compares the macro- and micronutrient intake between the two groups. There was a lower intake of energy ($p < 0.001$), carbohydrate ($p < 0.001$), total fat ($p = 0.001$), SFA ($p < 0.001$), PUFA ($P < 0.001$), trans-fatty acids ($p < 0.001$), iron ($p = 0.003$), and sodium ($p < 0.001$) in the SWL compared to the UWL group. On the other hand, there was no difference in protein ($p = 0.576$), cholesterol ($p = 0.587$), fiber ($p = 0.707$), calcium ($p = 0.175$), and folate ($p = 0.663$) intake between the two groups.

In addition, the intakes of different food groups have been outlined in Fig. 3. Evidently, the participants in the SWL group had significantly lower consumption of soft drinks ($p = 0.015$), sweets and sugars ($p = 0.00$), snacks ($p = 0.046$), pickles ($p = 0.007$), diary fats ($p = 0.016$), omega-6 sources ($p = 0.00$), red meat ($p = 0.00$), and refined grains ($p = 0.00$). In contrast, the UWL group consumed lower whole grains ($p = 0.030$), soybean ($p = 0.012$), poultry ($p = 0.00$), fruits ($p = 0.001$), vegetables ($p = 0.00$), and low-fat dairies ($p = 0.00$).

3.4. Association between cardio-metabolic biomarkers, liver enzymes, and success in weight loss

The differences in serum FBS, lipid profile, AST, ALT, ALP, and GGT between groups have been presented in Table 5. The Mann-Whitney *U*

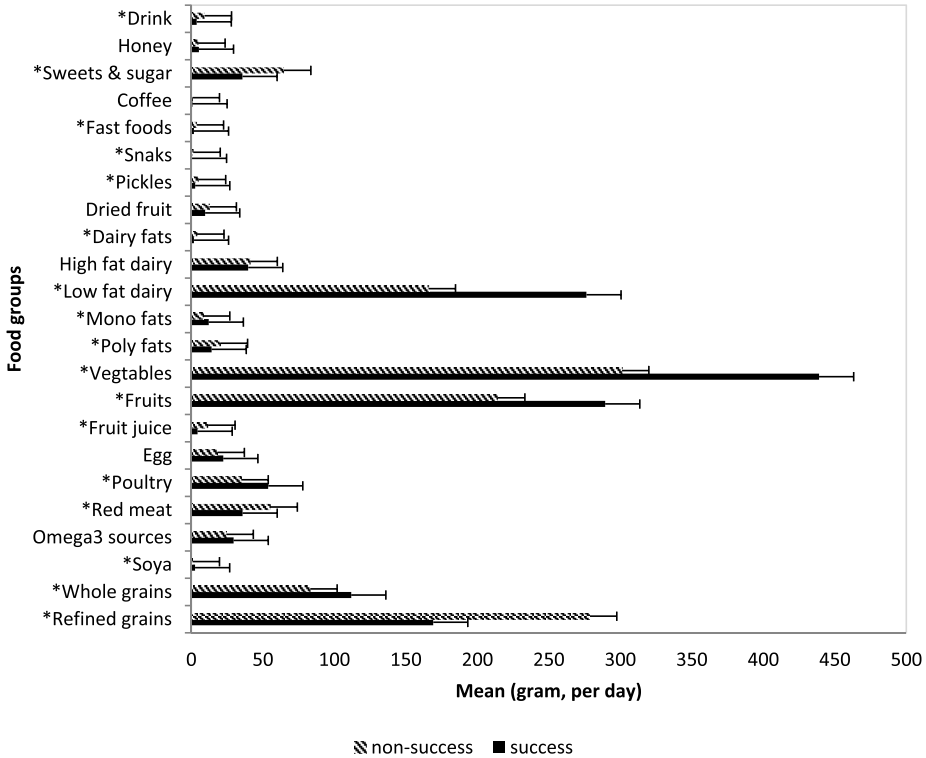

Fig. 3. Comparing the consumption of food groups in successful and unsuccessful weight loss maintainers. Values are presented as mean ± SD. Significant differences ($P < 0.05$) are indicated by asterisks (*). The significance of the differences was evaluated using the independent T-test or Mann-Whitney *U* test.

Table 5
Relationship between cardio-metabolic biomarkers, liver enzymes, and success in weight loss maintenance.

Variable [a]		SWL	UWL	P-value [b]
FBS (mg/dL)	Crude model	76.28 ± 4.89	79.49 ± 7.54	0.092
	Model 1[c]	75.33 ± 0.93	81.70 ± 1.19	< 0.001
TG (mg/dL)	Crude model	89.82 ± 36.07	85.02 ± 27.84	0.706
	Model 1[c]	91.22 ± 5.35	83.09 ± 6.87	0/728
Cholesterol (mg/dL)	Crude model	159.72 ± 21.67	159.24 ± 24.96	0.970
	Model 1[c]	158.80 ± 3.63	155.26 ± 4.67	0.299
LDL-c (mg/dL)	Crude model	95.21 ± 18.47	95.30 ± 17.87	0.992
	Model 1[c]	92.34 ± 2.36	91.96 ± 3.04	0.928
HDL-c (mg/dL)	Crude model	51.07 ± 10.84	46.76 ± 6.39	0.072
	Model 1[c]	49.78 ± 1.36	48.94 ± 1.75	0.731
AST (U/L)	Crude model	16.02 ± 5.88	16.42 ± 5.79	0.733
	Model 1[c]	15.70 ± 0.87	15.74 ± 1.11	0.984
ALT (U/L)	Crude model	8.76 ± 3.70	12.76 ± 9.00	0.070
	Model 1[c]	8.97 ± 0.78	10.39 ± 1.01	0.315
ALP (U/L)	Crude model	149.75 ± 31.81	148.51 ± 44.30	0.374
	Model 1[c]	146.46 ± 5.85	150.75 ± 7.52	0.682
GGT (U/L)	Crude model	13.11 ± 4.56	17.55 ± 7.15	0.001
	Model 1[c]	12.34 ± 0.69	15.94 ± 0.89	0.004

FBS, fasting blood sugar; TG, triglyceride; LDL-c, low-density lipoprotein; HDL, high-density lipoprotein; AST, aspartate transaminase; ALT, alanine transaminase; ALP, alkaline phosphatase; GGT, gamma-glutamyltransferase; SWL, successful weight loss; UWL, unsuccessful weight loss.
[a]presented as mean ± SD.
[b]Calculated using Mann-Whitney *U* test.
[c]Adjusted for age, physical activity, and energy intake.

test did not find any significant relationship between success in weight loss and TG ($p = 0.396$), cholesterol ($p = 0.586$), LDL-c ($p = 0.928$), HDL-c ($p = 0.731$), AST ($p = 0.984$), ALT ($p = 0.315$), and ALP ($p = 0.682$) after adjusting for age, physical activity, and energy intake. However, subjects with successful weight loss had significantly lower FBS ($p < 0.001$) and GGT ($p = 0.004$) levels compared to those in the UWL group.

4. Discussion

The primary aim of the present study was to investigate the association between success in weight maintenance and nutrients, food groups, and dietary patterns after one year of weight loss in women. PCA identified three major dietary patterns: a Mediterranean-like dietary pattern, high-fat-high-carbohydrate dietary pattern, and Iranian traditional dietary pattern. Results demonstrated a positive association between success in weight loss maintenance and Mediterranean-like and Iranian traditional dietary patterns after controlling for confounding variables. Moreover, there was an inverse association between adherence to high-fat-high-carbohydrate diet and success in weight loss maintenance. Maintainers had significantly lower consumption of soft drinks, sweets and sugars, snacks, pickles, dairy fats, PUFA sources, red meat, and refined grains. Conversely, regainers consumed lower whole grains, soybean, poultry, fruits, vegetables, and low-fat dairies. Findings also indicated a lower intake of energy, carbohydrate, fat, SFA, PUFA, trans-fatty acids, iron, and sodium in the SWL group. However, no difference was observed in protein, cholesterol, fiber, calcium, and folate intakes between groups.

The present study is in line with the previous studies reporting that maintainers intake lower energy (Raynor et al., 2011; Santos et al., 2017), total fats (Phelan et al., 2006; Raynor et al., 2011; Thomas et al., 2014), SFA (Karfopoulou et al., 2016), trans-fatty acids (Karfopoulou et al., 2016), carbohydrate (Santos et al., 2017), and sodium (Karfopoulou et al., 2016) compared to regainers and normal-weight individuals. It is not possible to present a definitive combination of nutrients to ensure that weight loss is maintained due to inconsistent reports from previous studies (Fogelholm et al., 2012). However, it appears that energy and macronutrient proportion are important determinants of weight loss maintenance.

There are few studies considering the major dietary patterns in weight loss maintainers. Raynor et al. (2011) observed that a low-energy-dense diet, mainly characterized by a higher intake of vegetables and whole grains, results in successful weight loss maintenance. The composition of the healthy dietary pattern (characterized by a higher intake of unprocessed cereal, fruit, vegetables, eggs, olive oil, beverages, low-fat dairies, and less intake of processed cereal, sweets, spreads/sauces, high-fat cheese, and junk food) in the study by Karfopoulou et al. (2017) was similar to the Mediterranean-like and Iranian traditional dietary patterns in our study. They found a positive association between success in weight loss maintenance and healthy dietary pattern in men but not in women (Karfopoulou et al., 2017). Similarly, in a 13-years cohort study, adherence to a healthy diet was related to less weight gain and risk of becoming obese only in men (Lassale et al., 2012). Nevertheless, in another study, adherence to the Mediterranean diet was associated with less weight gain both in men and women (Beunza et al., 2010). In the present study, there was a direct association between healthy dietary patterns (Mediterranean-like and Iranian traditional) and an inverse association between high-fat-high-carbohydrate diet as an unhealthy dietary pattern and success in weight loss. Also, maintainers had a lower intake of soft drinks, sweets and sugars, snacks, pickles, dairy fats, omega-6 sources, red meat, and refined grains, and higher intake of whole grains, soybean, poultry, fruits, vegetables, and low-fat dairies. This is consistent with the study of Raynor et al. (2011), reporting a higher intake of fruits, vegetables, and whole grains, and a lower intake of fried potato, refined grains, sweets, and alcohol servings in maintainers. Karfopoulou et al. (2017) did not find any differences in women, but male maintainers had a lower intake of regular soda, salty snacks, and alcohol, and higher low-fat dairy, nuts, and high protein foods. Furthermore, the study by Phelan et al. (2006) indicated a decrease in energy, grains (bread, cereal, rice, and pasta), fat, sweet, and dairy (milk, yogurt, and cheese) intake and an increase in fruit, vegetable, and protein source (meat, poultry, fish, beans, and eggs) intake in maintainers over time.

According to a systematic review, there is insufficient evidence for the role of dietary intake in the prevention of weight regain. In contrast, increase in fiber, whole grains, and dairy products intake and less consumption of refined grains, meat, sugar-rich foods and drinks may be effective in preventing weight gain in prospective cohort studies (Fogelholm et al., 2012). As mentioned earlier, energy balance is one of the key components of success in the maintenance of weight loss. As

expected, healthy dietary patterns provide lower calories. In contrast, high-fat-high-carbohydrate diet is associated with higher energy intake (Raynor et al., 2011). On the other hand, the SWL group had a higher physical activity compared to UWL. The higher physical activity of maintainers was also reported in several other studies (Karfopoulou et al., 2017; Kruger et al., 2006; Phelan et al., 2006). Moreover, other dietary factors, such as increasing protein (Karfopoulou et al., 2017; Santos et al., 2017) and fiber (Hjorth et al., 2017) intake and limiting dietary fats and carbohydrate (Raynor et al., 2011) are also considered to be helpful in maintaining weight loss.

Results of the present study revealed no differences in serum TG, cholesterol, LDL-c, and HDL-c between the SWL and UWL groups. Also, FBS and GGT were the only cardio metabolic risk factors with a significant difference between groups. The study by Wing et al. (1995) did not find lower lipid levels, blood pressure, waist-to-hip ratio, or percent body fat in maintainers compared to regainers. Contrary to our results, the study of Dandanell et al. (2017) reported better cardio-metabolic health (assessed by BMI, body composition, lipid profile, FBS, hexokinase II, citrate synthase activity, and VO_{2max}) in maintainers compared to moderate weight loss or weight regain. Two other studies also reported an improvement in cardio-metabolic profile in weight maintainers (Beavers et al., 2012; Wadden et al., 1999). In contrast, some studies show that the improvement in lipid profile is attenuated in the case of increasing the energy intake to its previous levels, even with maintaining weight loss (Eckel, 1999; Rössner and Björvell, 1987). This suggests that caloric restriction is more strongly associated with cardio-metabolic profile compared to weight loss.

It should be noted that weight loss needs to be maintained in the long term (more than four years) to be effective in the improvement of metabolic disease related to obesity (Dandanell et al., 2017). Since the present study was conducted one year after weight loss, assessment of cardio-metabolic profile in the following years may show different results. Also, the poor cooperation of the participants in blood sampling may affect the findings of the study. Moreover, most cardio-metabolic biomarkers evaluated in this study were in the normal range and there may have been no room for further improvement.

To the best of our knowledge, there is no study investigating the effect of weight maintenance on liver enzymes. In a previous study, lifestyle intervention and weight reduction were related to reductions in liver enzymes (Straznicky et al., 2012). The present study also showed a lower GGT in maintainers, but there was no association between ALT, AST, ALP, and success in weight reduction maintenance. Further studies are required to clarify the relationship between weight maintenance and hepatic injury biomarkers.

The strength of the present study lies in the fact that it is one of the few studies to investigate the relationship between success in weight loss maintenance and dietary patterns, nutrient intake, food groups intake, cardiometabolic biomarkers, and liver enzymes. The main limitations of the present study are the cross-sectional design, relatively small sample size, poor cooperation for blood sampling, as well as limitation of the participants to women, compromising the generalizability of the study. Also, using a questionnaire for collecting data may have increased the risk of recall bias due to its dependence on participants' ability to remind as well as their education level.

5. Conclusion

Results of the present study indicated a direct association between success in weight loss maintenance and Mediterranean-like and Iranian traditional dietary patterns. Moreover, there was an inverse association between adherence to high-fat-high-carbohydrate diet and success in weight loss maintenance. Participants who succeeded in maintaining their weight loss consumed more whole grains, soybean, poultry, fruits, vegetables, and low-fat dairies. Furthermore, participants with successful weight maintenance had lower levels of serum GGT and FBS.

Declaration of competing interest

None.

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