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The effects of diet-induced weight loss on asthma control and quality of life in obese adults with asthma: a randomized controlled trial

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ABSTRACT

Objective: While the effects of obesity on asthma are yet to be fully clarified, increased fat tissue is known to increase the severity of asthma and to impair asthma control. This study evaluated the effects of diet-induced weight loss on the characteristics of asthma in obese adults with asthma.

Methods: A total of 55 obese individuals (BMI ≥ 30.0) with asthma were enrolled in the study and randomized into the diet or control groups. The anthropometric measurements, asthma control test (ACT) scores, asthma quality of life questionnaire (AQLQ) scores, pulmonary function tests (PFT) and daily food consumption of the participants were recorded and compared at the baseline and at study completion.

Results: The changes recorded in body weight (diet -5.2 (4, 5); control, -0.1 (1.3)), ACT score (diet 2.0 (2.0); control 0.0 (1.7)) and AQLQ score (diet 0.8 ± 0.1 ; control -0.02 ± 0.5) of the participants in the diet group were significantly higher than in the control group ($p = 0.00$). The increases in forced expiratory volume in one second (FEV₁) and the forced vital capacity (FVC) measurements of the participants with weight loss of ≥ 5.0 percent were significant when compared to those with weight loss of < 5.0 percent ($p < 0.05$). While total energy uptake and carbohydrate consumption at the end of study were found to be decreased in the diet group, they had increased in the control group ($p < 0.05$).

Conclusion: Diet intervention improved asthma control and quality of life in obese patients with controlled asthma in this study. However to generalize this finding to all asthma patients, further studies including uncontrolled asthmatics are needed.

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KEYWORDS

Asthma; diet; obesity; pulmonary functions

Introduction

Obesity, which develops in relation to individual and environmental factors, is a complex and chronic disease that is characterized by abnormal body fat mass [1]. The prevalence of obesity is increasing continuously and is currently seen in almost one-third of the total populations of the United States and Europe [2]. Obesity is known to be associated with several chronic diseases, such as cardiovascular disorder, diabetes and cancer, and it is also recently been associated with respiratory diseases, particularly with asthma, with studies being carried out to explain the potential mechanisms underlying this relationship [3]. While the fundamental factor explaining the relationship between these two conditions is still unclear, suggested potential factors include the mechanical effects of obesity on the lungs, its effects on the immune system and inflammatory response, and the hormonal

changes caused by obesity [4]. Studies have also reported a higher frequency of asthma among the obese patients when compared to individuals with normal weight, supporting the potential relationship between these two conditions [5,6].

Fat tissue, which is considered to have a proinflammatory effect by being involved in inflammatory response, increases bronchial sensitivity in the asthmatic by causing systemic and local inflammation [7]. In addition, fat tissue increases oxidative stress and lipid peroxidation, and alleviates the symptoms of asthma by causing a release of such proinflammatory mediators such as TNF- α , IL-6 and leptin [8]. Some cross-sectional studies in the literature have reported lower asthma control scores and decreased pulmonary functions in obese individuals with asthma when compared to normal weight individuals [9–11]. These findings suggest that decreasing the amount of fat

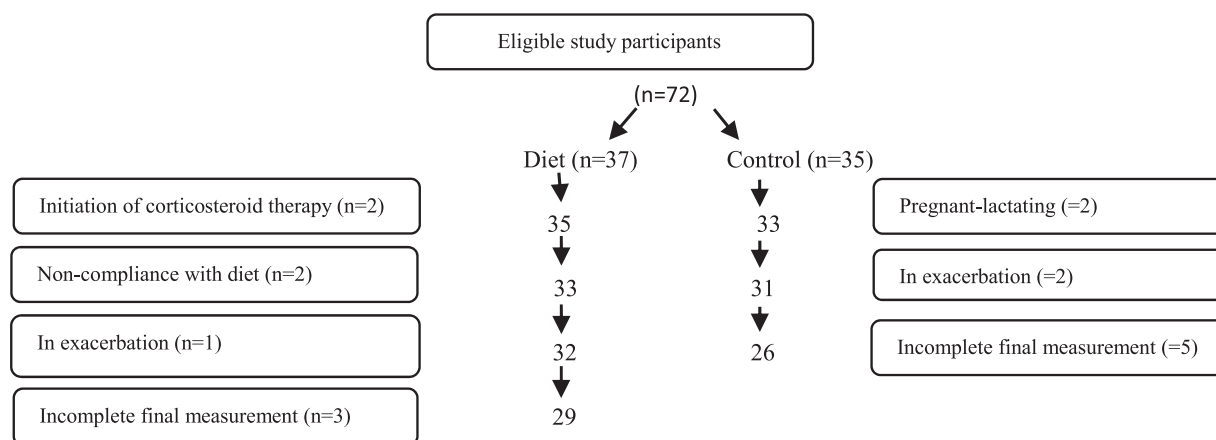


Figure 1. Number of participants based on inclusion/exclusion criteria.

tissue in obese asthmatic individuals may lead to an improvement in their symptoms. There have been a limited number of studies demonstrating the positive effects of weight loss provided by bariatric surgeries and energy-limiting diets on asthma characteristics [12,13]. That said, bariatric surgery represents the last step in obesity treatment, suggesting that studies should focus more on the effects of diet-induced weight loss on the course of asthma.

This study investigates the effects of diet-induced weight loss and the changes in consumed macro-micro nutrients on asthma characteristics, control and quality of life in obese asthmatic individuals.

Methods

Study design and subjects

This study was carried out in the Immunology and Allergy Department of Ankara University Medical Faculty between January 2017 and May 2017. Among the individuals who referred to the outpatient clinics between the above-mentioned dates, those who were diagnosed with asthma at least one year previously who were aged between 20 and 65 years and who had a body mass index (BMI) of $\geq 30 \text{ kg/m}^2$ were selected for inclusion in the study, and all of the participants provided voluntary informed consent prior to enrollment. Individuals already following a regular diet program, those with uncontrolled asthma, pregnant or lactating women, those using corticosteroids, those with cardiac rhythm disorders, those in the acute exacerbation period of asthma or those with a BMI of $< 30 \text{ kg/m}^2$ were excluded from the study (Figure 1). In the end, 55 participants were enrolled in the study and were randomly allocated to either the diet or the control group based on simple randomization method through the use of random number-generating

software (Microsoft Excel 2010). In order to avoid any interactions between the participants in the two groups, all measurements and interventions were made individually for each participant and in a separate room. The food consumption records of all participants were obtained, and a body analysis was performed at the baseline and at the end of the study. The study was approved by the Ankara University Medical Faculty Science Ethics Committee with approval number 19-967-16, and the necessary permissions were obtained before initiating the study.

Anthropometric measurements

All anthropometric measurements were obtained at the baseline and at the end of the study by a specialist while the participants were in a fasting state. The patients' heights were measured without shoes, and the measurements of waist and hip circumference were recorded while wearing light clothes. Body weight, total body fat (%), muscle mass, abdominal fat degree and body water ratio (%) measurements were obtained using a TANITA BC601 device (Tartı Medical, İstanbul, Turkey, <https://tarti.com/profesyonel-vucut-analizi-32.html>). BMI was calculated by dividing body weight by the square of height (kg/m^2), and participants with BMI $\geq 30 \text{ kg/m}^2$ were considered obese, based on classification of the WHO [1].

Diet intervention

A modest weight loss of 5%–10% is recommended for overweight and obese individuals, as it is a realistic weight-loss goal [14]. According to studies, approximately 10 weeks are enough time to reach 5%–10% weight loss [12,15]. Therefore, we decided that the 10-week period was sufficient for this research.

Past 24-h diet records were obtained from the participants in both groups at the baseline and at the end of the study (totally only twice and during face-to-face interviews). The data were evaluated using BeBIS software [16]. Accordingly, inappropriate eating habits were determined and weekly telephone contacts during the entire 10-week duration of the study were made with the participants to correct their habits and to keep them motivated.

A nutrition and 10-week weight loss diet program consisting of three main meals and three snacks daily was prepared by dieticians, taking into account the age, gender, physical activity and general eating habits of each participant in the intervention group. All physical activities (sleep, rest, sitting, working, etc.) undertaken by the participants over the last 24 h were recorded and energy expenditure was calculated by multiplying each activity with the individual activity index (Physical Activity Ratio – PAR). The average physical activity level (PAL) was calculated by dividing total energy expenditure by the basal metabolic rate (BMR). The BMR was calculated based on the Schofield equation. And finally the total energy requirement (PAL*basal metabolic rate) was calculated [17]. A diet was planned to consist of 10%–20% proteins, 45%–60% carbohydrates and 25%–30% fats [18]. The participants were informed of possible exchange food options and the amount of water they needed to consume, and it was aimed to reach an optimum nutrition level. The eating habits of the participants in control group were not intervened in any way, but all measurements were repeated at the end of the study.

Pulmonary functions, asthma control and quality of life

The pulmonary function of the participants was measured by a responsible nurse using a ZAN 100-branded (Germany) device. The measurements were recorded while the participants were in a sitting position on a fixed platform, and the best result out of three measurements was taken into account. The forced expiratory volume in one second (FEV₁), forced vital capacity (FVC), peak expiratory flow (PEF) and mean expiratory flow rate at 25%–75% of maximal expiration (MEF_{25–75}) measurements of the participants were obtained using a spirometry device. Expected values were determined after respiration maneuvers, based on each participant's age, gender and height recorded on the measurement device [19].

The validated Turkish version of the Asthma control test (ACT) was used to assess asthma control [20], which comprises five questions graded 1–5 that evaluate the level of influence on daily activities, daytime symptoms, nighttime symptoms, need of rescue medication and the individual's own perception of asthma control. The total score, obtained by adding the scores given to each question, ranges between 5 and 25, in which a higher score indicates better asthma control [21].

Quality of life assessments were performed based on an asthma quality of life questionnaire (AQLQ) which consists of 32 questions, each graded 1–7. A higher total scores reflect a better quality of life. The validated Turkish translation of the scale was used for this study [22].

Statistical analysis

In order to calculate the required sample size prior to the study, the ACT scores of the study participants in Dias-Júnior et al. were taken as a reference (diet 12.25 ± 1.08; control 11.8 ± 1.15), and a G Power 3.0.10 program was used for calculations. The study was completed with a 97.0% power (one tail). Data analyses were carried out using the SPSS-20 software package. Descriptive statistics were presented as mean ± standard deviation for normally distributed data, and as median (interquartile range, Q3–Q1) for non-normally distributed data, while nominal variables were presented as the number of cases and percentages (%).

A Students' *T*-test or Mann–Whitney *U*-test was used to compare the baseline variables between two groups. In-group differences after interventions into the dependent groups were analyzed by a Paired *t*-test or a Wilcoxon signed-rank test. The differences between two groups in terms of changes in each variable at the end of the study (Δ) were analyzed by a Students' *T*-test or Mann–Whitney *U*-test. Spearman and Pearson correlation tests were carried out to evaluate the power and direction of linear relations between two continuous quantitative variables. All statistical analyses were performed within a confidence interval of 95.0%, and *p* values of <0.05 were considered significant.

Results

General information

The study was initiated with 72 participants (37 on diet and 35 controls) and completed with 55

participants (29 on diet and 26 controls) (Figure 1). The majority of the study population were women, and the overall mean age was 50.4 ± 10.1 years. When the baseline demographical characteristics and measurements of the two groups were compared, no significant differences were noted in terms of gender, age, body composition, pulmonary functions, asthma control, AQLQ, level of education, smoking status, use of supplements or the presence of comorbidities. All of the participants were at least grade I obese, and the median BMI was $36.4 (5.2) \text{ kg/m}^2$ (Table 1).

Change in body composition

The baseline measurements of the participants were similar, with no significant difference between the two groups. Following 10 weeks of diet, the mean body weight of the participants in the diet group ($-5.2 (4.5) \text{ kg}$) decreased significantly when compared to the control group ($-0.1 (1.3) \text{ kg}$) ($p = 0.00$). BMI ($-2.0 (1.7) \text{ kg/m}^2$), waist circumference ($-5.0 (5.0) \text{ cm}$), total body fat ($-1.8\% (2.8)$), muscle mass ($-1.1 (1.5) \text{ kg}$) and abdominal fat level ($-1.0 (1.0) \text{ units}$) also decreased compared to the baseline values in the diet group, while an increase was noted in the body water ratio ($1.2\% (2.0)$). At the end of 10 weeks, inter-group changes in BMI ($p_1 = 0.001$), waist circumference ($p_2 = 0.001$), total body fat ($p_3 = 0.001$) and total body water ratio ($p_4 = 0.001$) were significantly more remarkable than within-group (diet group) changes ($p_1 = 0.0035$; $p_2 = 0.005$; $p_3 = 0.005$; $p_4 = 0.006$; respectively). There was no change in the body composition of the participants in the control group at the end of study (Table 2). When the changes in anthropometric measurements recorded at the end of the tenth week in both groups were compared, significant differences were noted in all values other than WHR ($p < 0.01$) (Table 2) (Figure 2).

Change in diet composition

While the total amount of calories ($-309.4 (257) \text{ kcal}$) and carbohydrate ($-35.4 (79.6) \text{ g}$) intake decreased at the end of the study in the diet group, they were found to be increased in the control group ($129.6 (283.7) \text{ kcal}$; $34.2 (61.8) \text{ g}$, respectively) ($p = 0.001$). The total amount of fat, saturated fat and poly-unsaturated fat consumption decreased significantly in the diet group when compared to the control group ($p < 0.001$). When the micronutrient intake was evaluated, increases were noted in the levels of vitamin C ($51.8 (26.6) \text{ mg}$), vitamin K ($224.4 (75.7) \mu\text{g}$) and

Table 1. General information of the participants.

	Diet	Control	<i>p</i> value
Number: <i>n</i>	29	26	
Age (years)	50.4 ± 10.4	50.3 ± 10.0	0.928
Gender (%women)	93.1	100	0.161
BMI (kg/m^2)	$37.5 (7.8)$	$35.7 (5.0)$	0.649
Waist circumference (cm)	107.0 ± 10.8	105.9 ± 25	0.680
WHR	0.88 ± 0.07	0.89 ± 0.07	0.828
Total body fat (%)	$44.3 (6.7)$	$43.3 (4.6)$	0.482
Muscle mass (kg)	$45.7 (8.1)$	$47.1 (6.6)$	0.938
Abdominal fat	$13.0 (5.5)$	$11.0 (3.5)$	0.187
Body water ratio (%)	$41.2 (4.6)$	$42.4 (3.5)$	0.358
FVC (%)	90.8 ± 16.1	94 ± 15.8	0.480
FEV ₁ (%)	93.8 ± 9.7	95.4 ± 8.3	0.433
FEV ₁ /FVC	$98.0 (17.0)$	$96.0 (11.7)$	0.694
PEF (%)	79.7 ± 18.8	82.8 ± 17.7	0.543
MEF ₂₅₋₇₅ (%)	49.8 ± 20.3	53.8 ± 22.9	0.513
MEF ₇₅ (%)	74.5 ± 26.7	78.7 ± 26.6	0.575
MEF ₅₀ (%)	55.8 ± 24.4	61.9 ± 28.3	0.415
MEF ₂₅ (%)	38.5 ± 15.0	39.0 ± 19.2	0.932
ACT score	21 (2)	21 (2.5)	0.152
AQLQ score	5.4 ± 0.6	5.7 ± 0.5	0.122
Asthma duration	10 (13.5)	10 (15)	0.992
Level of education (%)			
Primary school	69.0	68.0	0.325
Secondary-high school	17.2	24.0	0.202
University+	13.8	8.0	0.752
Active smoking (%)	6.9	8.3	0.601
Daily number of cigarettes (units)	5	2.5	0.248
Use of supplements (%)	17.4	15.3	0.769
Comorbidities (%)			
Diabetes	17.4	11.5	0.810
Hypertension	27.2	26.7	0.782
Hypercholesterolemia	13.7	–	0.720
Reflux	13.7	3.8	0.632

FEV₁: Forced expiratory volume in one second; FVC: Forced vital capacity; PEF: Peak expiratory flow; MEF: Mid-expiratory flow; ACT: Asthma control test; AQLQ: Asthma quality of life questionnaire.

Data were presented as median (IQR) or mean $\pm$ standard deviation.

* $p < 0.05$.

** $p < 0.01$.

magnesium ($127.7 (82.9) \text{ mg}$) consumption in the diet group, while no changes were noted in the control group (Table 2).

The changes in characteristics of asthma

While the FEV₁, FVC, PEF, MEF₂₅₋₇₅, MEF₇₅ and MEF₅₀ values increased in the diet group, decreases were noted in all values in the control group at the end of study. The most prominent differences between the two groups were recorded in the FEV₁, FVC and MEF₅₀ values ($p = 0.00$). Parallel to pulmonary functions, the AQLQ scores increased significantly in the diet group when compared to the controls ($p = 0.00$) (Table 3). Significant elevations in ACT scores were also observed in the diet group when compared to the control group, although the change did not reach the level of minimum important difference (three points).

When the participants in the diet group were classified based on their degree of weight loss, the changes in the FEV₁, FVC and AQLQ scores of the participants with weight loss of $\geq 5\%$ were found to

Table 2. Baseline and final body composition and macro–micro nutrient intake of participants.

	Diet (<i>n</i> = 29)		Control (<i>n</i> = 26)		Intergroup <i>p</i> value
	Baseline	Change (Δ)	Baseline	Change (Δ)	
Body weight (kg)	85.1 (19.7)	−5.2 (4.5)**	87.5 ± 10.7	−0.1 (1.3)	0.000
BMI (kg/m ²)	37.5 (7.8)	−2 (1.7)**	35.7 (5.0)	0 (0.6)	0.001
Waist circumference (cm)	107.0 ± 10.8	−5.0 (5.0)**	105.9 ± 25	−0.2 (1.0)	0.001
WHR	0.88 ± 0.07	−0.05 (0.04)	0.89 ± 0.07	0.01 (0.01)	0.156
Total body fat (%)	44.3 (6.7)	−1.8 (2.8)**	43.3 (4.6)	0.4 (1.6)	0.001
Muscle mass (kg)	45.7 (8.1)	−1.1 (1.5)**	47.1 (6.6)	0.1 (1.2)	0.007
Abdominal fat	13.0 (5.5)	−1 (1)**	11.0 (3.5)	0 (0.5)	0.001
Body water ratio (%)	41.2 (4.6)	1.2 (2)**	42.4 (3.5)	−0.3 (1.0)	0.001
Total calories	1854.8 (258)	−309.4 (257)**	1815.3 (3459)	129.6 (283.7)**	0.001
Carbohydrates (g)	213.4 (112)	−35.4 (79.6)**	174.0 (70)	34.2 (61.8)**	0.001
Protein (g)	54.4 (29)	5.6 (5.8)	66.4 (15)	−3.5 (10.6)	0.091
Fats (g)	87.0 (13)	−13.4 (24.9)**	93.2 (19)	−4.0 (10.0)	0.002
SFA (g)	29.6 (7)	−5.6 (7.6)**	28.8 (22)	−1.5 (12.8)	0.008
MUFA (g)	25.4 (6)	−0.1 (8.0)	29.3 (14)	−2.7 (11.4)	0.205
PUFA (g)	25.3 (5)	−9.6 (14.8)**	25.3 (5)	−0.9 (9.4)	0.004
Vitamin A (μ g)	881.8 (373)	82.2 (24.0)*	1257.1 (555)	63.9 (37.4)	0.673
Vitamin C (mg)	111.0 (88)	51.8 (26.6)*	230.7 (64)	−20.8 (47.9)	0.041
Vitamin E (mg)	26.1 (6)	−4.4 (10.6)	25.4 (23)	−0.5 (33.3)	0.091
Vitamin K (μ g)	407.0 (110)	224.4 (75.7)*	449.7 (66)	−25.7 (37.4)	0.035
Zinc (mg)	7.65 (4.0)	1.4 (1.6)*	9.2 (2.0)	−1.5 (1.4)	0.092
Magnesium (mg)	224.0 (34)	127.7 (82.9)**	259.6 (105)	3.6 (1.6)	0.003

BMI: body mass index; WHR: Waist hip ratio; SFA: Saturated fatty acids; MUFA: Mono-unsaturated fatty acids; PUFA: Poly-unsaturated fatty acids. Data were presented as median (IQR) or mean ± standard deviation.

**p* < 0.05.

***p* < 0.01.

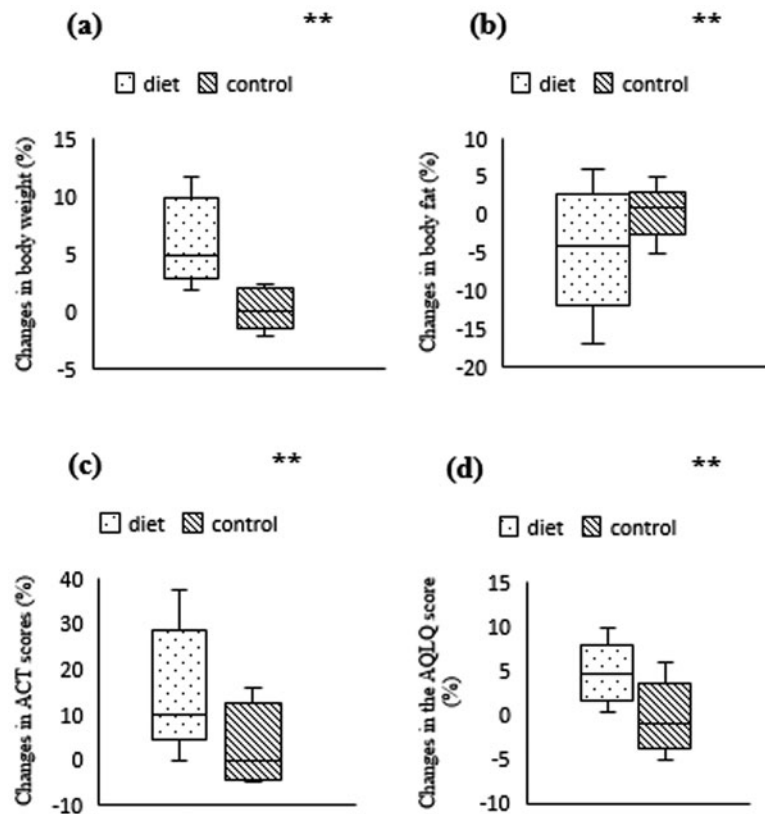


Figure 2. (a) Comparison of the changes in body weight of the participants in the diet and control groups (%). (b) Comparison of the changes in the total body fat of the participants in the diet and control groups. (c) Comparison of the changes in ACT scores of the participants in the diet and control groups (%). (d) Comparison of the changes in the AQLQ scores of the participants in the diet and control groups (%). ACT: Asthma control test; AQLQ: Asthma quality of life questionnaire. ***p* < 0.01.

Table 3. Baseline and final asthma characteristics of participants.

	Diet (<i>n</i> = 29)		Control (<i>n</i> = 26)		Intergroup <i>p</i> value
	Baseline	Change (Δ)	Baseline	Change (Δ)	
FEV ₁ (%)	80.4 $\pm$ 18.1	5.0 (10.5)**	84.9 $\pm$ 16.8	-4.3 (9.5)**	0.00
FVC (%)	90.8 $\pm$ 16.1	3.0 (12)**	94.4 $\pm$ 15.7	-4.0 (10.7)*	0.00
FEV ₁ /FVC	93.8 $\pm$ 9.7	0 (65)	95.6 $\pm$ 8.1	-2.0 (4.2)	0.042
PEF (%)	79.7 $\pm$ 18.3	4.1 $\pm$ 12.3	84.3 $\pm$ 17.6	-3.0 $\pm$ 13.8	0.071
MEF ₂₅₋₇₅ (%)	49.8 $\pm$ 20.3	6.0 (15.5)*	54.6 $\pm$ 22.8	-1.5(9.0)	0.004
MEF ₇₅ (%)	74.5 $\pm$ 26.7	5.9 $\pm$ 15.5*	79.5 $\pm$ 26.3	-3.4 $\pm$ 11.5	0.021
MEF ₅₀ (%)	55.8 $\pm$ 24.4	6.0 (9.0)**	62.8 $\pm$ 28.1	-4.0 (9.5)*	0.000
MEF ₂₅ (%)	38.5 $\pm$ 15.0	5.0 (11.5)*	39.4 $\pm$ 19.0	0 (8.7)	0.010
ACT	21.0 (2)	2.0 (2.0)**	21.0 (2.5)	0 (1.7)	0.000
AQLQ	5.4 $\pm$ 0.6	0.8 $\pm$ 0.1**	5.7 $\pm$ 0.5	-0.02 $\pm$ 0.5	0.000

FEV₁: Forced expiratory volume in one second; FVC: Forced vital capacity; PEF: Peak expiratory flow; MEF: Mid-expiratory flow; ACT: Asthma control test; AQLQ: Asthma quality of life questionnaire. Data were presented as median (IQR) or mean $\pm$ standard deviation.

**p* < 0.05.

***p* < 0.01.

Table 4. Changes in asthma characteristics of the participants in the diet group according to the degree of weight loss.

	<5% Weight loss	$\geq$ 5% Weight loss	<i>p</i>
<i>n</i>	15	14	
FEV ₁ (%)	1.0 (10.0)	4.5 (13.0)	0.011
FVC (%)	3.0 (10.0)	5.5 (13)	0.033
FEV ₁ /FVC	5.0 (10.0)	4.5 (13)	0.215
PEF (%)	3.0 (8.0)	2.0 (13.5)	0.882
MEF ₂₅₋₇₅ (%)	4.0 (13.0)	3.5 (12.75)	0.277
MEF ₇₅ (%)	7.0 (9.0)	8.0 (8.25)	0.147
MEF ₅₀ (%)	6.0 (14.0)	6.0 (9.5)	0.239
MEF ₂₅ (%)	4.0 (13.0)	3.5 (11.5)	0.347
ACT score	2.0 (1.0)	3.0 (2.0)	0.134
AQLQ score	0.18 (0.19)	0.28 (0.11)	0.004

FEV₁: Forced expiratory volume in one second; FVC: Forced vital capacity; PEF: Peak expiratory flow; MEF: Mid-expiratory flow; ACT: Asthma control test; AQLQ: Asthma quality of life questionnaire. Data were presented as median (IQR) or mean $\pm$ standard deviation.

**p* < 0.05.

***p* < 0.01.

be significant when compared to those with a weight loss of <5% (*p* < 0.05). The other pulmonary function test results and ACT scores of the participants did not differ significantly according to the degree of weight loss (Table 4).

When the correlations between the anthropometric measurements of the participants and their ACT and AQLQ scores were analyzed, the changes in body weight, BMI, waist circumference, total body fat and abdominal fat amount were found to be negatively correlated with the ACT and AQLQ scores, and positively correlated with the change in body water ratio (Figure 3).

Discussion

Soft fat tissue, which is produced as a result of increases in body weight, applies pressure to the chest wall and limits the movements of the thoracic cage and the diaphragm during respiration [23]. In obese individuals in particular, the decrease in the total

surface area of respiratory airways due to the deposition of fat tissue reduces total lung capacity [24]. In such cases, weight loss is recommended to improve the symptoms of asthma in obese asthmatics [25]. While BMI is a frequently used index for the monitoring of obesity, it does not reflect body fat distribution. It is known that body fat distribution is as important as BMI, and in particular, total body fat and abdominal obesity are associated with asthma [26]. In this study, following an energy-limiting diet of 10 weeks, the total body weight, total body fat, waist circumference, abdominal fat content and BMI values decreased significantly in the participants in the diet group when compared to those in the control group. Correlated with these decreases, significant improvements were achieved in asthma control, quality of life and pulmonary functions of individuals in the diet group when compared to the control group. The increases in FEV₁ and FVC values, as well as ACT and AQLQ scores, were particularly pronounced in individuals with a weight loss of more than 5.0% when compared to those with a lower degree of weight loss.

The most important targets during the follow-up of asthmatic patients are to achieve asthma control and to increase quality of life. The current diagnosis and treatment guidelines for asthma underline the importance of nonpharmacological treatment approaches in achieving these targets [21]. Body weight decreases in obese asthmatic individuals are associated with an increased level of daily activity and a better quality of life [26]. In the study of Maniscalco et al. performed on obese asthmatic women, the ACT scores of the participants increased after diet-induced weight loss [13]. In another study, Scott et al. reported decreases in body weight and the level of abdominal obesity, and increases in the ACT and AQLQ scores in

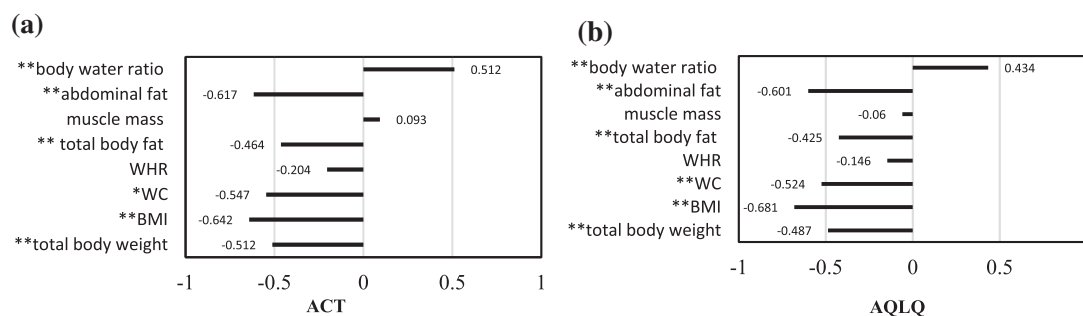


Figure 3. (a) Correlation between changes in ACT score and anthropometric measurements (Δ). (b) Correlation between changes in AQLQ score and anthropometric measurements (Δ). BMI: Body mass index; WC: Waist circumference; WHR: Waist-hip ratio; ACT: Asthma control test; AQLQ: asthma quality of life questionnaire. * $p < 0.05$, ** $p < 0.01$.

asthmatic individuals after applying a combined therapy of diet and physical activity [12]. The ACT and AQLQ scores of the individuals were found to be increased also in other studies reporting weight loss after diet and bariatric surgery [13,27]. In this study, we found that the ACT and AQLQ scores of the participants increased in correlation with the decrease in their body weight, and this change was negatively associated with the changes in BMI, waist circumference, total body fat and abdominal fat content. However, as patients had controlled asthma in both groups, it is hard to suggest that the improvement in quality of life seen in the diet group was due to weight loss solely. Improvements in quality of life detected post-intervention might also be related to increases in the improved affect and physical activity levels by losing weight.

Randomized controlled studies have also shown improvements in respiratory functions after decreases in body weight [12,13]. In this study, the FEV₁, FVC, FEV₁/FVC, MEF₂₅₋₇₅, MEF₇₅, MEF₅₀ and MEF₂₅ values of the participants in the diet group increased with weight loss when compared to the values recorded in the controls. Similar to our findings, Scott et al. [12] reported significant improvements in the respiratory functions of individuals with more than 10.0% weight loss when compared to those who had lost less than 10.0% of their body weight. A number of other studies in the literature have also recorded significant improvements in respiratory functions after decreasing abdominal obesity [7,12,28]. The respiratory functions of individuals also improved significantly after bariatric surgery, which is associated with the most pronounced decreases in abdominal obesity [27,29]. When data on asthma control, quality of life and pulmonary function parameters are considered altogether, it may be concluded that decreases in body weight in cases with obesity and asthma facilitate asthma control.

Due to the respiratory problems they experience, asthmatic individuals are inclined to having sedentary lifestyles. In addition to insufficient physical activity, the intake of excessive calories and carbohydrates also triggers this tendency to obesity, and this vicious circle has a negative effect on the quality of life of asthmatic individuals [8]. The results of this study have shown that the amount of calories, carbohydrates, total fats, saturated fats and PUFA consumed by the individuals in the diet group was significantly lower than in the control group. Considering the consumption of saturated fats and PUFA in particular results in inflammatory response, improvements in the symptoms of asthma in the individuals in diet group may be associated with a decreased consumption of such fats. The transformation of a conventional diet to a modern diet with changes in eating habits reduces the total amount of consumed antioxidants, vitamins and minerals, and alleviates the symptoms of asthma [30]. In this study, marked increases were noted at the end of the tenth week in the consumed amounts of vitamin C, vitamin K and magnesium in individuals in the diet group when compared to the control group. In a study by Barros et al. [31], the ACT scores of individuals increased with the increased consumption of nutrients rich in Vitamin C. Another study carried out with asthmatic individuals showed that the diet inflammatory index (DII) score was inversely proportional to antioxidant intake, and a 1-unit increase in DII score was associated with a 3.44-fold decrease in the FEV₁ value [32]. In addition to decreases in body weight, it may also be argued that the difference in dietary nutrient composition in the diet group contributed to asthma control.

This study has some limitations. Firstly, the study group consisted of well-controlled asthma patients and the effect of diet intervention was observed on these subjects. Although asthma control and quality of life improved in the diet group, this result could

not be generalized for all asthma patients as uncontrolled asthmatics were not included in this study. On the other hand, this study may provide a future perspective by giving the idea that less controlled asthma would benefit more from diet-induced weight loss. Secondly, the effects of dietary interventions were evaluated on asthma control, functional parameters and quality of life in obese patients in this study, but changes in inflammatory cytokines were not analyzed. No blinding was performed, due to the nature of the study, which may have introduced some bias. Although the evaluations of those in the diet and control groups were carried out in separate rooms to avoid any interactions, those who were not put on a diet after randomization may have been disappointed, leading to a lower level of motivation and potential errors in the quality of life and asthma control evaluations of these individuals. Food consumption data were recorded for two days, one at the beginning and one at the end of the study. Although the two-day food consumption data may not be sufficient to determine overall eating behavior, it provides more realistic results than methods involving longer recording durations, because some patients may hide their food consumption in the following days due to dietitian control.

There were much more women included in the study than men, but this difference in the prevalence of asthma between genders is a global fact. As a result of the effects of sex hormones after puberty, asthma is more commonly seen among women than men [33]. Similarly, in the study of Dias Junior et al. [14], the number of women was significantly higher than the number of men.

Despite these limitations, the strength of the study is increased by its randomized, controlled and prospective design and a long follow-up duration. In order to increase the participants' adherence to diets, weekly telephone contacts were made with them over the entire ten-week period and potential negligences were avoided. Taking one step beyond the previous studies in the literature, detailed anthropometric measurement variables and macro-micro mineral consumptions were compared between the two groups, which allowed a detailed interpretation of the effects of the changes in both eating habits and anthropometric measurements on pulmonary function.

Conclusion

In conclusion, the findings of this study show that diet-induced weight loss in obese well-controlled

asthmatic individuals improves respiratory function, asthma control and quality of life. These improvements were even more pronounced with increasing levels of weight loss. No lifestyle intervention was made in this study, and so the effects of diet alone were investigated. Future studies involving physical activity plus dietary interventions and monitoring the effects on inflammatory cytokines in uncontrolled asthma patients as well may provide better insight into the relationship between obesity and asthma.

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The authors report no conflicts of interest.

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