



Effect of Aerobic Training and *C. vulgaris* Intake on Lipid Profile and Leptin in Obese Women

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Abstract

Background: Regular physical activity can reduce the complications of obesity. *Chlorella vulgaris* (*C. vulgaris*) is recognized as a rich source of health promotion.

Objectives: The aim of this study was to evaluate the effect of aerobic training and *C. vulgaris* intake on lipid profile and leptin in obese women.

Methods: We randomly divided 32 obese women into control (C), aerobic training (AT), *C. vulgaris* (CV), and aerobic training plus *C. vulgaris* (AT+CV) groups. Interventions were performed for eight weeks. *C. vulgaris* was used at the dose of 1200 mg/day. The aerobic training included activities on a treadmill with 65% - 80% of maximum heart rate (MHR) (three sessions/week). Blood samples were taken before and after the interventions.

Results: The body weight, body mass index (BMI), leptin, triglyceride, cholesterol, HDL-C, and LDL-C significantly improved in the AT and AT+CV groups compared to the control group ($P < 0.05$). There was no significant difference between the AT and AT+CV groups ($P > 0.05$).

Conclusions: Aerobic training can improve the lipid profile and leptin in obese women by reducing weight, increasing oxygen uptake, and improving lipid oxidation. Nevertheless, the effect of *C. vulgaris* was not detected individually. However, the effect of training may be due to the modification of exercise-induced responses by *C. vulgaris* properties. Therefore, there is a need for further investigation of *C. vulgaris* physiological function in the field of sports medicine.

Keywords: Exercise, Herbal Supplements, Obesity, Adipokines

1. Background

Overweight and obesity are associated with a variety of health-related risks, including cardiovascular disease, hypertension, and diabetes mellitus. Medical experts recommend non-pharmacological methods, including exercise training and nutritional recommendations for weight loss and prevention of many diseases (1). On the other hand, fatty tissue also has an endocrine role in this regard through the secretion of adipokines. Leptin is one of the secreted hormones by fatty tissues. Leptin is a protein structurally similar to cytokines that is involved in the regulation of weight and energy homeostasis. Fatty tissue is the main source of leptin secretion, but leptin is also secreted from other sites, including skeletal muscle, breast epithelium, placenta, and the brain. The main role of leptin is sending information about the status of the body's energy storage to hypothalamus receptors, thus helping reduce

eating (2). In fact, leptin acts as a warning mechanism for regulating body fat. It has been shown that serum leptin has a high correlation with body fat percentage and it decreases the amount of leptin after weight loss (3). Leptin, in its natural state, is an important regulator of energy homeostasis, but it can cause many problems if it appears in abnormal amounts in the blood (4). Exercise and physical activity are of factors influencing homeostasis and energy balance (5). Different results have been reported about the effect of exercise on leptin levels (6, 7).

Lipid profile control, i.e. lowering cholesterol, triglycerides, LDL-C, and increasing HDL-C levels, is also very important. High levels of LDL-C and low levels of HDL-C may lead to cardiovascular diseases (8). HDL-C prevents LDL-C oxidation due to the anti-inflammatory properties of its enzymes. Improved lipid profiles including increased HDL-C and decreased cholesterol and LDL-C, occur in response to training (9, 10).

The use of natural herbal supplements has recently attracted the attention of many researchers. *Chlorella vulgaris* (*C. vulgaris*) is a single cell green alga recognized as a good source of protein, fat-soluble vitamins, choline, fibers, and minerals (11, 12), and has been identified as a source of health promotion for various types of disorders such as ulcers, constipation, anemia, lipid disorders, atherosclerosis, blood glucose and blood pressure reduction (13, 14). *C. vulgaris* is a rich source of antioxidants such as lutein, alpha and beta-carotene, ascorbic acid, and tocopherol, which are capable of inhibiting free radicals. It seems that the use of *C. vulgaris* can help in regulating the physiological function of the body in malignant diseases due to oxidative stress (15-19). Animal studies have shown that the prescription of *C. vulgaris* powder can improve the lipid profile and decrease lipid peroxidation in mice (20, 21).

It is worth mentioning that obesity in most societies is increasing due to the sedentary lifestyle. On the other hand, the public's general approach to using exercise rehabilitation and medicinal herbs has increased for several reasons. Previous studies confirmed the effects of aerobic training and medicinal plants separately on lipid profiles and health indicators. However, the simultaneous effect of sports exercises and medicinal herbs has not been studied. It is important to carry out these studies, especially in women whose health is important to the community.

2. Objectives

Based on the background literature, the study aimed to investigate the simultaneous effects of aerobic training and *C. vulgaris* intake on lipid profile and leptin in obese women.

3. Methods

Thirty-two obese women were randomly assigned to control (C), aerobic training (AT), *C. vulgaris* (CV), and aerobic training plus *C. vulgaris* (AT+CV) groups (n = 8 each). Before the beginning of the study, the nature and objectives of the study were explained to the participants in a meeting and their written consent was obtained. Based on physician examination and approval, all subjects had complete physical health.

The general characteristics of the participants were measured a week before intervention (Table 1). Forty-eight hours before and after the intervention, blood samples were taken from participants in the four groups in a 12-hour fasting state to measure the levels of leptin, triglyceride, total cholesterol, LDL-C, and HDL-C.

The CV and AT+CV groups consumed four pills (300 mg) of *C. vulgaris* daily (one before breakfast, two before lunch, and one before dinner). *C. vulgaris* supplement with the trademark of Algomed was prepared from Farday-e-Sabz Company, Iran.

Aerobic training was performed three sessions a week for eight weeks. Each exercise session consisted of 10 minutes of activity by 60% of maximum heart rate (MHR) to prepare participants for exercises and let them familiarize with the device (warming), followed main training and cooling. The aerobic training program included activities on a treadmill with 65% of MHR for 16 minutes in the first week, which increased to 80% of MHR for 30 minutes in the eighth week with two minutes added time and 5% added intensity every two weeks. The MHR and the target heart rate (THR) were calculated using the heart rate reserve (HRR) equation.

$$HR_{max} = 208 - (0.7 \times \text{age}) \quad (22)$$

$$THR = [\%intensity \text{ desired} \times (HR_{max/peak} - HR_{rest})] + HR_{rest}$$

Blood samples were taken in a steady state of the middle vein (basilica) by 5-cc syringes. The samples were collected into sterile tubes containing K3EDTA. Both heparin and EDTA tubes were placed on ice and then they remained at room temperature for several minutes. Serum was isolated from the plasma by centrifugation for 10 minutes at 3500 rpm. All blood samples were stored frozen at 20°C until they reached the lab where they were frozen at -70°C. Lipid profiles including TG, TC, LDL, and HDL were also obtained by the clinometric method using the Biorox kit. Leptin was measured by the ELISA method using the Mercodia kit made in Sweden.

For statistical analysis of the obtained data, each variable was first described using a mean and standard deviation. Then, using the Kolmogorov-Smirnov test, the normal distribution of data was determined. The homogeneity of variances was confirmed by the Levene's test. Therefore, in order to compare and evaluate the changes in four study groups before and after the intervention, the ANOVA with repeated measurements was used. The significance level was set at $P \leq 0.05$. All statistical calculations were performed using SPSS version 16 software. In addition, Excel 2003 software was used for drawing statistical curves.

4. Results

In the present study, leptin (EF = 0.74, F = 80.65, P = 0.001) and LDL-C concentrations (EF = 0.56, F = 37.01, P = 0.001) reduced significantly (Figures 1 and 2). HDL-C (EF = 0.47, F = 24.89, P = 0.001) increased significantly after eight weeks of treatment (Figure 3). The body weight (EF = 0.86, F = 172.13, P = 0.001), body mass index (BMI) (EF = 0.86, F =

Table 1. General Characteristics of Participants

Groups	Age, y	Height, cm	Weight, kg		BMI, kg/m ²	
			Pre-Test	Post-Test	Pre-Test	Post-Test
AT	25 ± 4.17	164.62 ± 4.30	82.15 ± 4.62	79.25 ± 4.26	30.55 ± 0.45	29.26 ± 0.27
CV	26 ± 4	158.87 ± 7.54	78 ± 7.28	77.37 ± 7.11	30.89 ± 0.34	30.64 ± 0.49
AT+CV	28.50 ± 1.77	154.87 ± 8.13	74.62 ± 7.68	70.25 ± 7.22	31.08 ± 0.63	29.26 ± 0.82
Control	25.50 ± 3.66	160.50 ± 9.28	78.62 ± 8.81	78.25 ± 9.09	30.48 ± 0.43	30.31 ± 0.27

Abbreviations: AT, aerobic training; BMI, body mass index; CV, *C. vulgaris*.

172.18, $P = 0.001$) (Table 1), TG (EF = 0.50, $F = 28.77$, $P = 0.001$) and total cholesterol (EF = 0.53, $F = 32.05$, $P = 0.001$) (Table 2) were affected by training and they improved significantly. This improvement included a significant increase in the HDL-C concentration and a reduction in other measured parameters. These changes were due to the effect of exercise. No significant effect was found for the interaction of *C. vulgaris* and training or *C. vulgaris* alone.

5. Discussion

In the present study, continues aerobic exercise improved the measured variables independently. HDL-C is the main carrier of cholesterol and is the main factor inhibiting LDL-C peroxidation. Researchers have shown that the mechanism of HDL-C changes following exercise training is complex. Enzymes such as lipoprotein lipase (LPL), triglyceride hepatic lipase (HL), and cholesteryl ester transfer protein (CETP) play important roles in altering the HDL-C concentration. LPL through hydrolyzing plasma triglyceride during aerobic exercise is the most important factor in changing the HDL-C concentration (23).

Danavan et al. showed the beneficial effects of moderate-intensity and long-distance exercise on LDL-C and VLDL (24). Considering the use of fat as a fuel source during and after the initial return, it seems to be a factor in LDL-C and VLDL reduction. Performing exercise training can increase the amount of type I lipoprotein and increase the activity of the LPL enzyme. In addition, LPL causes the catabolization of the lipid section of LDL-C. Therefore, LDL-C is expected to decrease. LPL activity triggered by exercise may be a factor in reducing TG. The duration of exercise seems to be effective in reducing triglyceride levels (25). Regular aerobic exercise seems to improve lipid profiles. A general look at the research on the effect of exercise on lipid profiles indicates that exercise training rarely affects TC and LDL-C levels unless it is accompanied by diet and weight loss (26, 27).

Theodor et al. examined the effect of aerobic training, resistance training, and combined exercise on 56 el-

derly patients with coronary artery disease. Resistance training led to a significant increase in muscle strength, while aerobic training led to a significant improvement in lipid profiles and apolipoproteins. Combined exercise also improved both physiological (muscle strength) and biochemical variables (lipid profile, apolipoprotein and inflammation) (28). Zanetti et al. reported that after 12 weeks of nonlinear resistance training, TC, TG, LDL-C, and CRP levels decreased in the exercise group while HDL-C levels increased in this group (29).

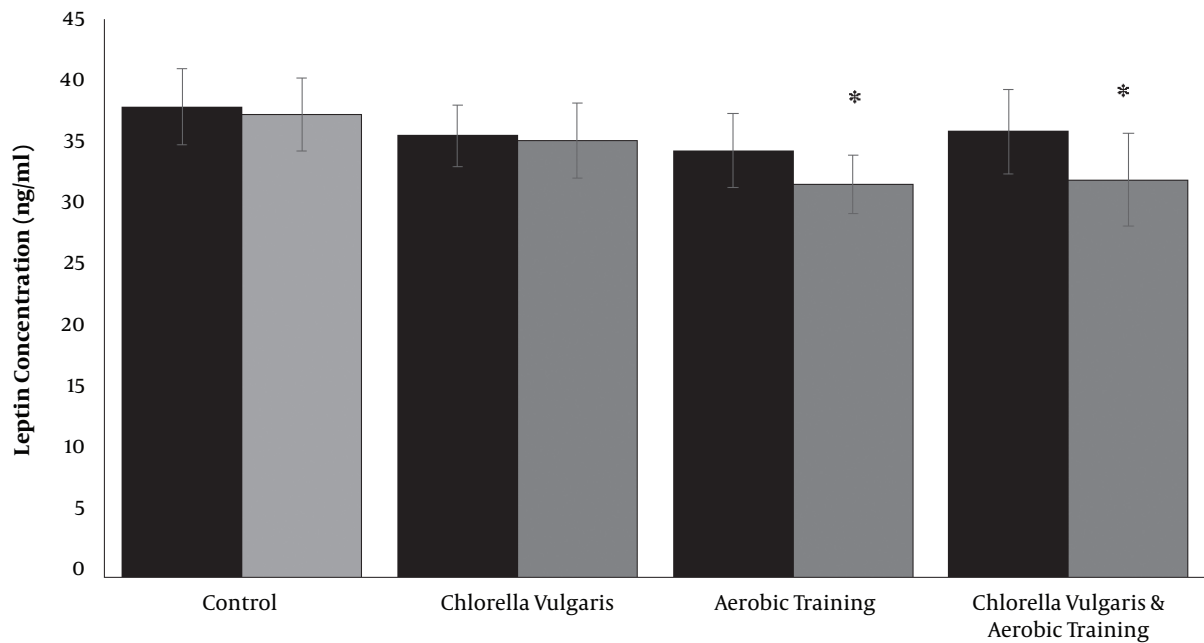
Based on the findings of the present study, weight and BMI decreased with aerobic training in the two groups that performed aerobic training. Wong et al. (30) and Chen and Young (31) reported weight loss following exercise training. Exercise and physical activity have been accepted as a way to facilitate weight loss and improve body composition. In the mild or moderate physical activity, due to increased energy demand in the muscles of participants in the activity, fat oxidation increases compared to the resting condition. On the other hand, physical activity has shown to reduce appetite, especially after exercise. Moreover, the major part of muscle fatty acids during physical activity is supplied through triglyceride lipolysis (32). Moderate-intensity exercise increases the amount of blood flow to adipose tissues. Unlike aerobic training, intense or resistance activity, despite the high-energy consumption, can decrease the total fat oxidation compared to moderate activity.

In addition, the results indicated a decrease in serum leptin levels with aerobic training most probably due to weight loss and BMI reduction after adaptation to aerobic training. Research about long-term training periods has shown the least controversy and most emphasis on decreases in serum leptin levels (33). It has also been suggested that leptin secretion is correlated with changes in body weight, BMI, body fat percentage, and waist circumference. Aerobic training probably cannot cause changes in leptin levels without causing a decrease in body weight (34, 35). On the other side, Jurimae et al. showed leptin decreased in men and women without significant changes in

Table 2. Significant Reduction in Triglyceride and Cholesterol Concentrations After Eight Weeks of Aerobic Training in Obese Women

Group	Cholesterol, ng/dL		Triglyceride, ng/dL	
	Pre-Test	Post-Test	Pre-Test	Post-Test
AT	211.49 ± 23.38	199.95 ± 20.80	165.62 ± 40.90	138.68 ± 36.44
CV	208.51 ± 16.80	207.07 ± 20.14	165.51 ± 34.84	163.32 ± 33.28
AT+CV	202.26 ± 20.46	187.76 ± 17.83	163.21 ± 48.76	154.31 ± 34.27
Control	210.31 ± 14.33	210.75 ± 11.81	156.38 ± 39.49	165.43 ± 36.21

Abbreviations: AT, aerobic training; CV, *C. vulgaris*.

**Figure 1.** Significant reduction in leptin concentrations after eight weeks of aerobic training in obese women. *A significant difference compared with control group.

body weight and BMI. They stated that exercise was effective on the levels of leptin more in women than in men. Since body weight did not change, the researchers mentioned that leptin levels in women may decrease, regardless of weight loss (36).

In summary, physical activity is the most important factor in energy consumption. Since absorbed energy can regulate leptin gene expression positively or negatively, changes in energy consumption through exercise may also affect leptin levels. Physical activity can be an important determinant of leptin levels (33). Exercise-induced stress is a potent and specific regulator of leptin secretion. Physical activity or changes in the flow of fuel in circulating hormonal concentrations and in energy consumption due to physical activity can lead to changes in leptin concentrations. Leptin changes are related to other clinical indica-

tors. It has been shown that decreased leptin levels in response to exercise are associated with increased VO₂max and insulin sensitivity (37).

It can be noted that decreased leptin concentration induced by exercise is associated with changes in energy balance, insulin sensitivity, and hormonal changes related to carbohydrate and fat metabolism. Research to find leptin changes in obesity conditions is of utmost importance. Therefore, to change the levels of leptin and its dependent hormones, such as insulin, thyroxine, triiodothyronine, and cortisol, the intensity and duration of the training program should be appropriate. An interesting point in this type of exercise is the improvement of maximum oxygen intake, which can be an important indicator of health promotion, along with body fat and weight loss. Kim et al. stated that *C. vulgaris* is a single cell alga that plays a proac-

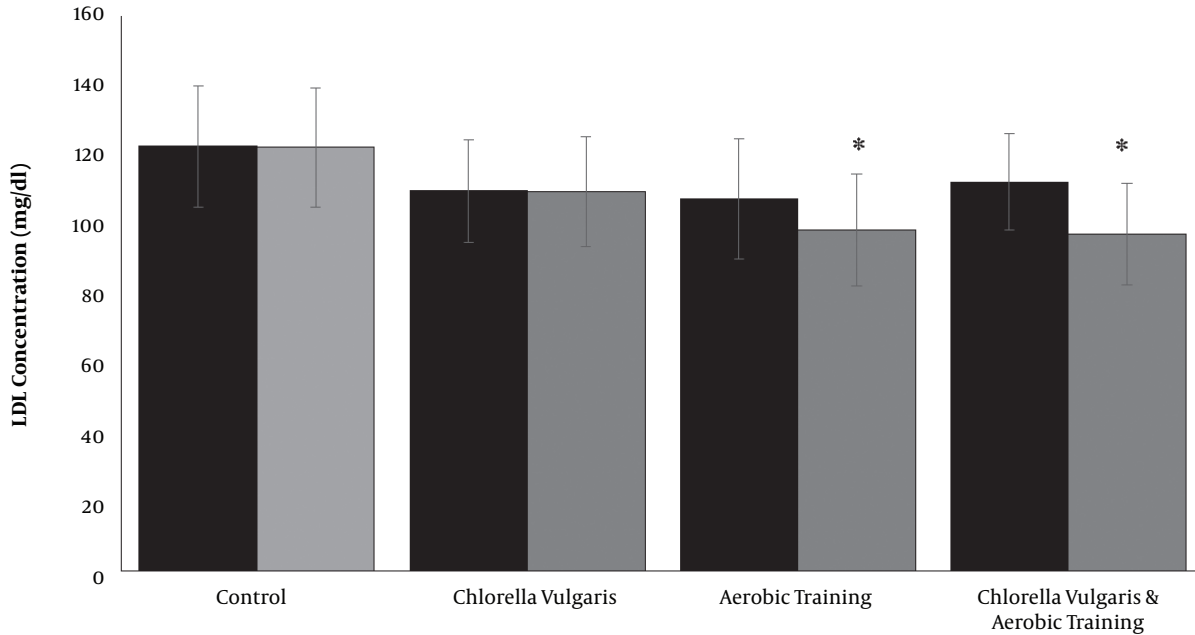


Figure 2. Significant reduction in LDL-C concentrations after eight weeks of aerobic training in obese women. *A significant difference compared with control group.

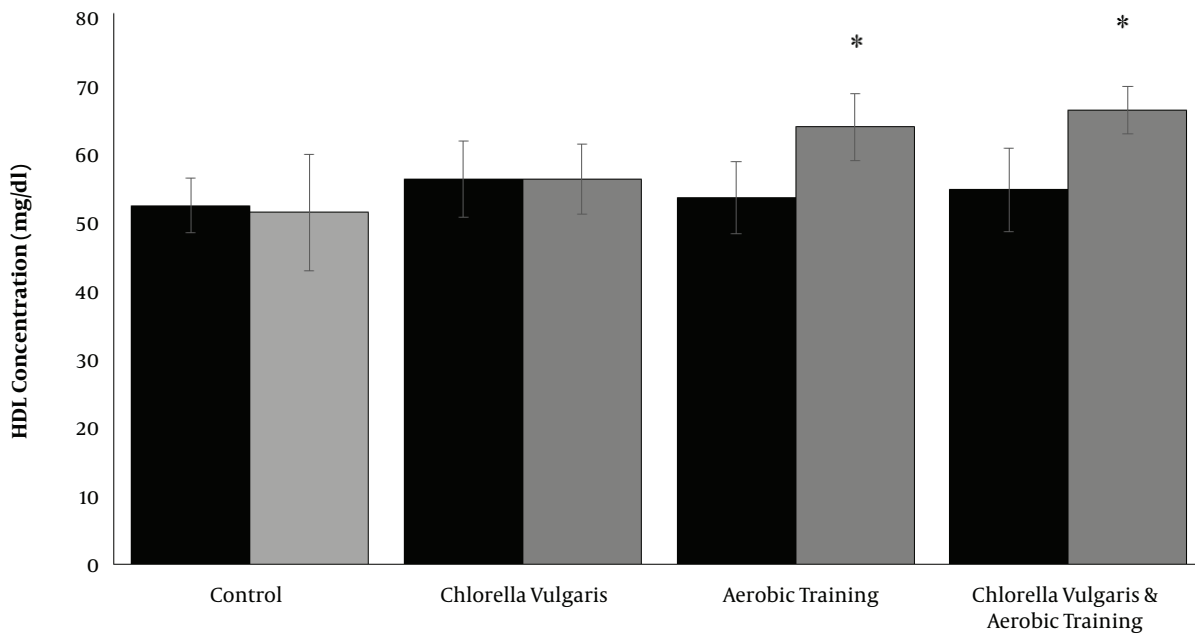


Figure 3. Significant increases in HDL-C concentrations after eight weeks of aerobic training in obese women. *A significant difference compared with control group.

tive role in maintaining serum cholesterol levels against high cholesterol food consumption (38).

In the present study, there was no difference between the training and *C. vulgaris* + training groups. The most

important reason for this observation is probably the effect of exercise on lipid tissue and lipid profiles. This suggests that *C. vulgaris* probably has more anti-inflammatory effects and lower effects on adipose tissue. Since fat loss is associated with a decrease in the secretion of leptin, it is possible that higher doses of *C. vulgaris* could reduce the amount of fat due to high fiber, thus affecting the whole fat.

The effects of *C. vulgaris* hypolipidemia may be attributed to the high content of fiber, glycolipid, and phospholipid content (13). Fiber is attached to fatty acids and bile acids in the intestine and causes them to excrete in the stool. On the other hand, *C. vulgaris* decreases triglycerides by improving insulin resistance, lipolysis, and consequently decreasing free fatty acids (39). The high content of niacin in *C. vulgaris* is also responsible for lipid-lowering effects, especially decreased triglyceride and increased HDL-C. It seems that omega-3 fatty acid found in *C. vulgaris* plays a role in decreasing lipid profile, especially triglyceride. In addition, polyphenols have inhibitory effects on pancreatic lipase to prevent lipid absorption. The findings of this study did not show the effectiveness of Chlorella, which can be attributed to the lack of dietary control or its low dose and duration of intake (20). However, previous findings about the simultaneous effect of exercise and Chlorella are limited.

5.1. Conclusions

Based on the findings of the present survey, it is concluded that eight weeks of aerobic training can significantly improve the lipid profile and serum leptin of obese women and prevent cardiovascular and other diseases caused by obesity. On the other hand, Chlorella supplementation did not show any significant effect on any of the variables and its addition to aerobic training did not increase the training benefits, possibly due to the short duration and low dose of Chlorella consumption. However, since there has been no research on the simultaneous effect of aerobic training and Chlorella supplementation, in order to obtain better results, future research should be conducted with the control of other influential variables. It is better to consider the antioxidant properties of supplements because it is possible that the training effects can be hindered by inhibitory oxidant agents of Chlorella supplementation.

Supplementary Material

Supplementary material(s) is available [here](#) [To read supplementary materials, please refer to the journal website and open PDF/HTML].

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Footnotes

Authors' Contribution: Contribution of the authors is in accordance with the research regulations.

Conflict of Interests: The authors declare no conflict of interests.

Ethical Approval: The present study was approved by the Ethics Committee of Islamic Azad University, Mahallat Branch (code 20021404942013).

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Patient Consent: Written consent was received from the participants.

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