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The Simultaneous Effect of Curcumin Extract Supplementation and Aerobic Exercise on Leptin and Adiponectin Gene Expression in Visceral Adipose Tissue of Rats Receiving A High-Fat Diet

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ABSTRACT

Introduction: Herbal remedies can be helpful in the prevention and treatment of obesity, overweight, and related disorders. However, how aerobic exercise and curcumin supplementation interact with adipose tissue is still unclear. This study aimed to determine how aerobic exercise and supplementation with curcumin extract would affect leptin and adiponectin gene expression in visceral adipose tissue of rats fed a high-fat diet.

Methods: In this study, 50 male rats were divided into five groups of equal size: control, high-fat diet, curcumin and high-fat diet, aerobic exercise and high-fat diet, and aerobic exercise and curcumin and high-fat diet. Five sessions per week of aerobic exercise were performed for six weeks at a speed of 25 to 29m/min for 20 to 45 minutes. Rats were given high-fat food emulsion of 0.5mg/kg of body weight per day for six weeks to simulate high-fat food groups. One-way analysis of variance (ANOVA) and Tukey's post hoc test were employed in SPSS software version 22 to analyze the results.

Results: There was no difference between the short-term effects of aerobic exercise, a high-fat diet, and curcumin extract on adiponectin gene expression in male rats (P=0.05). The short-term effects of aerobic exercise, a high-fat diet, and curcumin extract on the leptin gene expression in adipose tissue in male rats were comparable and not significantly different. Consuming curcumin, an antioxidant, and brief exercise affected the fat gene expression.

Conclusions: Based on the results, both agent alone decreases or increases the expression of the adiponectin and leptin genes in fat, and when both agents are consumed simultaneously, the expression increases.

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Introduction

Chronic low-grade inflammation associated with obesity can lead to metabolic dysfunction and coronary artery disease (CAD) [1,2]. Adipokines are made by adipose tissue and have the potential to either promote or inhibit inflammation [3]. Disorders linked to obesity may be exacerbated by impaired adipokine release or synthesis [1,4].

A sedentary lifestyle and changes in diet toward high-fat, high-energy-dense foods are related to the growing westernization, urbanization, and mechanization in most of the world's nations [5]. Developing nations are experiencing a nutritional transition that causes them to consume more energy-dense foods and fewer micronutrients, which may contribute to overweight and obesity [6].

Additionally, there is a direct relationship between the degree of obesity and the amount of dietary fat. Animal studies [7] have shown that high-fat diets lead to greater food intake and weight gain than high-carbohydrate diets. Caloric density, satiety characteristics, and post-absorptive processing all play a significant part.

The brain, liver, pancreas, muscles, immune system, and adipose tissue are just a few ofthe numerous organ's leptin and adiponectin have

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been shown to affect. Inflammation and immune response are affected by them; adiponectin is anti-inflammatory, whereas leptin is pro-inflammatory [8]. Low plasma levels of adiponectin and high plasma levels of leptin are characteristics of obese people [9].

The peptide leptin, released by white adipose tissue, has pro-inflammatory properties and is essential for the central regulation of metabolism and body weight. Higher leptin levels in obese subjects than in lean subjects can explain the inflammatory conditions associated with obesity and possibly the disease development [10]. Leptin regulates, synthesizes, secretes, and functions inflammatory cytokines like TNF-a, IL-6, and CRP. However, leptin is involved in the occurrence of cardiovascular diseases by influencing processes such as angiogenesis and increasing oxidative stress and calcium deposition in endothelial cells and blood vessels, proliferation of smooth muscle cells, and increasing cell adhesion molecules such as ICAM-1 [11]. In contrast to other cytokines derived from adipose tissue, adiponectin has anti-inflammatory, anti-atherogenic, and anti-diabetic properties [13]. Adiponectin is the most prevalent plasma protein in fat and glucose metabolism, vascular biology, and energy balance [12]. Adiponectin levels are decreased in individuals with insulin resistance, obesity, and coronary artery disease [14]. Adiponectin acts by inhibiting the synthesis and action of TNF-a and IL-6. Reducing the production of CRP inhibits inflammatory responses, and lowering ICAM-1 gene expression and improving endothelial function slow the progression of atherosclerosis [15]. Physical activities is one of the effective behavioral interventions in modulating inflammatory mediators [16]. Aerobic exercises independently or by modulating general risk factors such as obesity and associated abnormalities reduce the probability of cardiovascular diseases in older people [18].

Polyphenols and flavonoids are among the herbal and natural compounds that significantly impact leptin and adiponectin [18]. Curcumin is the primary natural polyphenol found in the rhizome of Curcuma longa (turmeric) [18]. It has been known for thousands of years that curcumin has therapeutic characteristics and may benefit one's health [19]. In addition, curcumin is used worldwide in various ways, such as a spice, antibiotic, anti-inflammatory, preservative, or coloring agent, as well as a supplement in the form of capsules or powder [20]. Numerous disorders, such as inflammatory and degenerative ailments, cancer, dyslipidemia, metabolic syndrome (MetS), and obesity, have been related to curcumin's positive effects [21–24]. Additionally, numerous studies have demonstrated that curcumin's antioxidant and anti-inflammatory properties account for most of its advantages [22]. Research shows curcumin exhibits anti-inflammatory, cell-protective, apoptotic, and antioxidant properties. Further, curcumin promotes the production of PGC-1 and further suppresses Adipo-R2 via activating AMPK. Curcumin also offers additional cardiovascular preventive benefits that help patients and people at risk of obesity from (high-fat) diets improve their heart health. Curcumin has been shown to have many positive effects, but there are not enough papers in this regard. Moreover, curcumin inhibits the protein breakdown pathway and affects leptin and adiponectin levels in the visceral fat tissue of obese rats [23]. Adipose tissue inflammation contributes to the emergence of eralsev diseases connected to obesity. According to the research included in this review, supplementing with curcumin causes obese and overweight people to produce much less inflammatory cytokines and have higher plasma levels of adiponectin. Curcumin can also control several molecular targets in adipose tissue, such as signaling pathways, transcription factors (NF-kB, NLP3), and other intricate regulatory systems, suppressing or lessening chronic low-grade inflammation. In vitro studies are needed to better understand curcumin's mechanisms of action and clinical trials in people, given its widespread use as a supplement for its health-promoting effects. A gender-based controlled experiment is conducted to determine genuine efficacy. For specific recommendations on curcumin intake, it is necessary to obtain consensus on the effects of curcumin and identify potential disparities between men and women when it comes to curcumin treatment.

Several human studies have demonstrated that curcumin decreases inflammation in obesity and illnesses by harmonizing anti-inflammatory and pro-inflammatory variables due to curcumin's interactions with a wide range of biomolecules, including transcription [25, 26]. Additionally, several studies have shown that curcumin may

help overweight people with metabolic syndrome lose weight when diet and lifestyle changes [27, 28]. In Vari (2021), a lipophilic polyphenol called curcumin was purified from the turmeric plant Curcuma longa. Since turmeric has numerous health benefits, it has historically been used in traditional Asian medicine. Spices are often used in new dishes around the world. Curcumin may have anti-inflammatory properties, according to numerous research. Obesity is a significant contributor to the chance of developing lsevera chronic illnesses, such as type 2 diabetes, cardiovascular disease, and several cancers. Obesity is expected to have a significant role in the pathogenesis of chronic diseases by causing the systemic and localized development of low-grade chronic inflammation in adipose tissue. Different signaling pathways are involved in the molecular mechanisms that start the inflammation generated by obesity instead of the conventional inflammatory response from infections. The inflammatory process in obese persons is brought on by inadequate nutritional intake, resulting in alterations in fat in adipose tissue on both a quantitative and qualitative level and by various chemicals working as endogenous ligands to stimulate immune cells. Defective adipocytes release adipocytokines, inflammatory cytokines, and chemokines to draw immune cells to adipose tissue and intensify the inflammatory response throughout the body [29].

Less attention has been paid to leptin and adiponectin changes that persist after exercise, and the results of current studies are conflicting. The effect of exercise on preventing nonalcoholic fatty liver disease onset showed that 16 weeks of optional running exercise at 50–75% of maximal oxygen uptake on a treadmill could express the hepatic nonalcoholic fat leptin gene in rats. Therefore, the correlation between energy expenditure and physical and sports activity is one of the critical reasons for the efficacy of exercise in treating fatty liver disease [30]. According to Sirico et al. (2020), new information on adipose tissue physiologic and inflammatory status associated with obesity may be relevant for the long-term prevention of obesity-associated chronic disease by modulating the adiponectin level. A systematic review was conducted with meta-analyses of electronically identified randomized controlled trials. A database search was conducted to evaluate the effect of physical exercise on leptin and other inflammatory markers without concomitant dietary intervention in children aged <18 years with a BMI >95th percentile by age and sex. The results showed that physical exercise decreased the amount of leptin compared to a control group that did not receive any lifestyle modification. The authors concluded that whether physical exercise reduces inflammation in obese children remains to be determined. Sarmi (2016) concluded that exercise improves endurance resistance, and combined exercises minimize insulin resistance. Combination exercise reduces insulin resistance. No significant differences in leptin levels were observed between the groups. As defined by Sarmi et al. (2016), exercise improved the fat-to-leptin ratio in mice, and combined exercise enhanced insulin resistance.

Based on the literature mentioned above on the correlation between exercise, diet, and intake of Curcumin extract supplements, this study looks at the correlation between curcumin supplement intake, aerobic exercise, and the expression of Leptin and Adiponectin genes in the visceral adipose tissues of rats, which were fed with a high-fat diet.

Materials and Methods

This developmental research uses research results to improve and refine human society's behavior, method, tool, device, product, structure, and pattern and, ultimately, to meet a need.

This randomized clinical trial design was conducted under the code of ethics no. IR.IAU.M.REC.1400.031 from Islamic Azad University. Animal subjects (males) were employed because human subjects could not be accessed due to space limitations, ethical considerations, and time limitations. First, permits were obtained, and then male and female rats were housed separately under the Iran Society for Protection of Laboratory Animals (SPLA) guidelines. The sampling method was random, and the study volume included 50 2-month-old male rats. The sample size was calculated using G POWER software based on the statistical analysis of variance with alpha error level (0.05) and power (0.85) equal to 50 rats. The sample was randomly distributed into five groups: control, high-fat, curcumin, and high-fat. The group distribution was as follows: Exercise + HFD + Curcumin + HFD + HFD.

This study selected 50 two-month-old Sprague-Dawley male field rats weighing 200 and 250g (taken from Zanjan University of Medical Sciences) as statistical samples. The rats were kept in controlled conditions for two weeks to familiarize themselves and adjust to the living, nutritional, and training conditions. Then, the rats were divided into five groups and matched according to body weight and categorized equally in weight. The control group served as a reference group and was compared with the experimental group to determine the independent variable effect. Samples were stored for two weeks under novel conditions (temperature =22±2°C, ambient humidity =50±5%) and a light-dark cycle =12:12 hours) to avoid stress and changes in physiological conditions. All subjects ate standard food and drank standard water. During these two weeks, the samples went through a familiarization program in which they were shown how to use the animal electric treadmills (ST008) (designed and manufactured in Tabriz University) (this smart animal treadmill has five separate channels). The smart program controls all related parameters, such as positive and negative slope, speed, and time. During these two weeks, the level of electric shock remained stable at a value of 0.1mV. The treadmill incline was 0% during the familiarization period, and the treadmill speed was 10 to 15m/min. The training duration was 5 to 10min/day. The tested rats were housed in a polycarbonate cage manufactured by the exclusive company of Razi Rad. The cage size was approximately 21×34×54cm. The wood chips were replaced every two days, and the cage was washed and cleaned weekly. Five rats were housed in each cage during this (compatibility with environment) period. The rats are susceptible to respiratory diseases. Therefore, dust and ammonia from the rat urine should not build up in the breeding/maintenance hall. The airflow should be changed 10 to 15 times per hour in the hall to avoid this. In this study, an ordinary ventilated animal house was used, which was kept 24 hours a day, seven days a week. After the study, the rats were randomly assigned to five groups after a weight match [33].

High-Fat Diets

In all the groups consuming high-fat diets, high-fat food emulsions containing 1.5mg/kg body weight daily were used. The composition of the diet was intended for rate in addition to the standard rodent diet [34].

Aerobic Exercise

The group completed an aerobic exercise program on an animal-smart electronic treadmill five days per week (Saturdays, Sundays, Mondays, Tuesdays, Thursdays, and Fridays) for six weeks. The intensity of aerobic activities in human subjects was determined by different ratios of maximum oxygen consumption, maximum heart rate, reserve heart rate, and speed of exercise performance. The activity intensity was controlled through the speed of running on the treadmill and its slope because of using an animal subject and the unavailability of the necessary facilities to accurately determine the intensity of the activity. The training protocol was designed based on Nashio et al. (2001), who determined the intensity of activity using the speed and slope of the treadmill for each training week after estimating the maximum oxygen consumption of rats and access to the necessary facilities. Thus, the strain, sex, age, and approximate weight of the present study subjects were also matched based on the mentioned study. Rats in each group ran on a treadmill at 11 meters per minute for five sessions a week, lasting 30 minutes each. A treadmill endurance training study was conducted on rats for one week at an average 6m/min speed and an 11-degree incline. Subsequently, the rats were subjected to endurance training at an 11m/min speed for five weeks, lasting thirty minutes daily for five weeks (33).

Curcumin Supplementation

Curcumin extract was prepared by ordering from the Medicinal Plants Research Center. The consumption of 3mg of curcumin per body weight of rats per day was considered. The daily consumption for a 70kg rat was 2.4g, fed to the rats by gavage to obtain this amount of curcumin, considering the content of 5% of curcumin [33].

RNA Extraction, cDNA Synthesis, and Gene Expression

The PCR master mix for preparing cDNA was first mixed in a microtube with a sampler proportionally to the kit protocol. Subsequently, 0.5ml of the required RNA was added to the master mixture. Finally, the ingredients were pooled in an ice pool. The real-time PCR (RT-PCR) method was employed to determine whether the gene(s) or mRNA(s) expressing the

desired proteins were present. CDNA was then used by the recommended protocol for PCR using Viragen's Mix Red. The primers were taken from the vials and mixed with TE buffer according to their proportions. Then, 180ml of the buffer, 10ml of the forward primer, and 10ml of the reverse primer were poured into the chosen tubes. The applied primer was designed for two different genes, Leptin and Adiponectin, with the following sequence, length, and type:

Shapiro-Wilk was used to check the normal distribution of the variables, and Levene's test was used to examine the homogeneity of variables. The ANCOA test was used to compare the means of the research variables between the groups. The extra Bonferroni was used to determine how significant the difference between the groups was. The significance level for all the tests was $p<0.05$, and all the statistical procedures were conducted via SPSS software version 22.

Table 1. High-fat food composition table

Ingredients	Amount (grams)
Corn oil	400
Sucrose	150
Whole milk powder	80
Cholesterol	100
Multivitamin	2.5
Twin 80	36.5
Propylene glycol	31
Salt	10
Distilled water (ml)	300

Table 2. Endurance training protocol

	Warming up	the speed of endurance training on the treadmill	cooling down	the entire training time
The first week	5min, 50-60% VO2max	The speed is 25 meters per minute with a 15% slope	5 min 50-60% VO2max	20 Min
The Second week	5min, 50-60% VO2max	The speed is 26 meters per minute with a 15% slope	5 min 50-60% VO2max	20 Min
The Third week	5min, 50-60% VO2max	The speed is 27 meters per minute with a 15% slope	5 min 50-60% VO2max	30 Min
The Fourth week	5min, 50-60% VO2max	The speed is 28 meters per minute with a 15% slope	5 min 50-60% VO2max	40 Min
The Fifth week	5min, 50-60% VO2max	The speed is 29 meters per minute with a 15% slope	5 min 50-60% VO2max	45 Min

Table 3. Specifications of the primers used in the Real Time PCR process

Gene name	Primer sequence	Product length (open pair)
leptin	Forward: 5'- CGATGAGGAGCAATCCAGTCC-3' Reverse: 5'- CTCAATTTCAGCCAGACGGC-3'	228
Adiponectin	Forward: 5'- CGTGCTTGCCATTCAGAAA -3' Reverse: 5'-ATATACATCGGTCTCGGTGG -3'	244

Results

There was a normal distribution of data across all variables, as demonstrated by the Shapiro-Wilk test. Consequently, a one-way analysis of variance test was conducted to evaluate the data. The results of the descriptive characteristics of subjects (i.e., pre-test, post-test weight, and leptin gene expression in mice) in the groups are presented in Table 4.

Regarding the expression of this gene, there is a big difference between the control and high-fat diet groups, the control and high-fat diet + exercise groups, the high-fat and high-fat + exercise groups, and the high-fat and curcumin

groups. Regarding Leptin gene expression, there was a significant difference in the control group, high-fat diet, control, high-fat diet + exercise, high-fat diet, and curcumin groups.

Table 4. Findings related to the descriptive characteristics of the subjects

group	Pre-test weight		Post-test weight		Leptin gene expression		Leptin gene expression	
	Mean	standard deviation	Mean	standard deviation	Mean	standard deviation	Mean	standard deviation
Control	2.06	3.02	2.25	3.11	1.38	0.043	0.48	0.052
high-fat diet	2.06	3.62	2.87	3.32	2.52	0.047	0.52	0.029
Curcumin and high-fat diet	2.06	3.11	2.51	2.09	0.83	0.045	1.64	0.039
Aerobic exercise and high-fat diet	2.06	2.89	2.75	2.11	2.24	0.072	0.83	0.038
Aerobic exercise and curcumin and high-fat diet	2.06	3.18	2.38	3.32	1.91	0.037	0.80	0.064

Table 5. Results of analysis of variance between groups of leptin and adiponectin gene expression in five groups

	leptin gene expression		adiponectin gene expression	
group	P	F	P	F
Control **high-fat diet** **Curcumin and high-fat diet** **Aerobic exercise and high-fat diet** **Aerobic exercise and curcumin and high-fat diet**	⁎<0.001	6.54	⁎<0.001	3.84

Table 6. Bonferroni follow-up test results

The variable	groups	significant level
Adiponectin gene expression	Control group and high-fat diet group	0.001
	Control group and high-fat diet group + exercise	0.003
	high-fat diet group and high-fat diet group + exercise	0.001
	High-fat diet group and high-fat diet group, exercise + curcumin	0.001
Leptin gene expression	Control group and high-fat diet group	0.012
	Control group and high-fat diet group + exercise	0.003
	High-fat diet group and high-fat diet group, exercise + curcumin	0.001

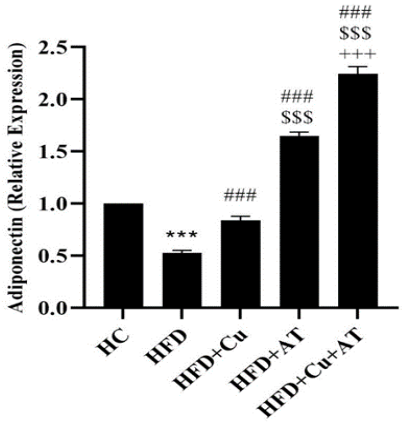

Figure 1. Adiponectin gene expression values in visceral fat tissue of rats in research groups
healthy control group: HC, obese with high-fat diet: HFD; Fattened with high-fat food+curcumin: HFD+Cu; fattened with high-fat food + exercise: HFD+AT; Fat with high fat food+exercise+curcumin ***(P=0.001) significant decrease compared to HC group
###(P=0.001) significant increase compared to HFD group
$$$ (P=0.001) significant increase compared to HFD+Cu group
+++(P=0.001) significant increase compared to HFD+AT group

Discussion

As a result of the difference between the means of the control group and the other groups, it appears that the expression of adiponectin genes decreased in the high-fat diet group and the group with curcumin. Increasing obesity and metabolic syndrome demand a cost-effective way to slow them down. Adipose tissues are active endocrine organs that secrete certain substances known as adipokines. Adipokines such as Leptin and Abdominocetin work both autocrine (paracrine) and endocrine (endocrine) (35). Adipokines regulate glucose and lipid metabolism, energy balance, feeding behavior, insulin resistance, inflammation, the immune system, adipose tissue production, and blood coagulation [36]. Based on studies, the hormone leptin is responsible for sensing the amount of fat in the blood, and its concentration is proportional to the amount of fat stored in the body, increasing adipose tissue production in obesity. On the other hand, adipokines are not inversely related to body fat mass and are involved in regulating glucose and lipid balance [37]. Studies have shown that decreased plasma adiponectin levels are associated with metabolic syndrome, insulin resistance, cardiovascular disease, and hypertension [38]. During fat storage, the metabolic activity of fat cells decreases, resulting in a less responsive response to insulin. The low ability of adipose tissue to quickly respond to insulin and other hormones is considered a factor causing insulin resistance, and the incidence of chronic diseases through these metabolic disorders is significantly increased. Exercise-induced physiological pressure, systemic hormone concentrations, and calorie intake affect plasma adiponectin concentration. Some researchers have stated that adiponectin has an inverse relationship with fat percentage and accumulation in adipose tissue [39]. Dutil et al. showed that six months of aerobic training and a daily reduction of 500 calories through sports activities cause a significant increase in blood adiponectin. In addition, adiponectin had a significant relationship with duration, intensity, and volume of exercise [40].

Curcumin may inhibit the 11 βHSD1 enzyme responsible for activating cortisol [41]. Elevated cortisol levels in adipocytes lead to central obesity. Additionally, curcumin has been suggested to reduce obesity by inhibiting premature adipocyte differentiation by inhibiting the transcription factor, PPAR-c, and increasing monophosphate-activated protein kinase activity, followed by lipolysis [41]. Previous meta-analyses have suggested that curcumin may reduce energy expenditure [42]. Another potential mechanism of action for curcumin/turmeric in obesity is hormonal. According to meta-analyses, curcumin consumption may reduce leptin levels and increase adiponectin levels, altering appetite and energy regulation. In contrast, overexpressing adiponectin hormones through activation of AMPK can increase glucose utilization and oxidation of fatty acids, promoting weight reduction. However, curcumin supplementation over six weeks did not significantly influence weight loss and BMI, which may be attributed to the short duration of supplementation. In addition to the lipid profile indicators improvement, there was a decrease in total cholesterol, triglyceride, and LDL levels and an increase in HDL and CRP levels. The changes were not massive and aligned with Sahai et al. regarding curcumin supplementation changing lipid profile levels in women with PCOS for six weeks [43]. Boam et al. also found no change in the lipid profile of older people by curcumin supplementation for six months and detected a relationship between cholesterol levels and curcumin intake [44]. In addition, a meta-analysis and a systematic study did not indicate any alterations in lipid profile levels following curcumin supplementation. However, some studies have suggested that curcumin supplementation may improve lipid profiles. A cross-over study showed a significant decrease in serum triglycerides in obese participants after 30 days of supplementation with curcumin with no alterations in other components of lipid profiles [45]. Tabrizi et al. also found that taking curcumin significantly reduced triglycerides and overall cholesterol but did not affect HDL or LDL levels [46]. Curcumin has been shown to stop free radicals from forming, and its antioxidant properties could prevent inflammation and complications from hyperlipidemia. In addition, curcumin has been shown to inhibit the activity of FAS (Fatty Acid Synthesis) and increase the oxidation of β-fatty acids with the potential to decrease fat stores effectively. Consequently, curcumin can regulate lipid metabolism through this mechanism [47]. Li et al. concluded that a high dose of turmeric reduces the food intake of

rats, probably due to its strong taste or because of the fibers in turmeric that cause the release of digestive hormones, which can stimulate satiety [34]. Rostami et al. revealed that interval training with turmeric supplementation affected visceral and subcutaneous fat in obese women [33]. Curcumin increases lipolysis by increasing the enzymes in fat oxidation, such as carnitine palmitoyl transferase-1 and hormone-sensitive lipase, and decreasing the activity of fatty acid synthesizing enzymes, such as acetyl decarboxylase and the enzyme that creates triglyceride reserves, such as glycerol triphosphate acyltransferase-1 (GPAT-1), inhibit lipogenesis [49].

Previous studies have demonstrated a marked rise in the amount of Leptin after consuming high-fat meals. Leptin levels vary depending on the diet and dosage used. This significant rise in Leptin levels may indicate inflammatory conditions after consuming a high-fat diet. The precise mechanism of the Leptin response to a high-fat diet is yet to be elucidated. The induction of neutrophils may explain the Leptin response after consuming high-fat foods. Leptin resistance is associated with the disruption of leptin transfer from the blood-brain barrier. Therefore, leptin's JAK/STAT signaling is reduced, and the cytokine effect-3 (SOCS-3) suppressor is induced. Weakening of leptin sensitivity in the brain causes additional accumulation of triglycerides in the tissue, fat, muscle, liver, and pancreas, leading to impaired insulin sensitivity. Therefore, leptin contributes to insulin resistance, and exercise enhances insulin sensitivity. Exercise inhibits insulin resistance in tissues sensitive to leptin in obese individuals because leptin plays a significant role in insulin resistance [50]. Akbarpour et al. (2013) investigated the effect of twelve weeks of aerobic exercise on BMI, fat profile, body fat percentage, and some adipokines. A decrease was found in leptin, fat percentage, and BMI, and an increase was detected in adiponectin. The reduction in leptin was consistent with the decline in body fat, associated with the observed changes in energy balance, improved insulin sensitivity, and changes in fat metabolism. Since leptin levels correlate strongly with body fat percentage, after adolescence, girls' leptin levels increase and boys' decrease [51]. A limitation of this study is the lack of measurement for adiponectin, leptin, and other genes that regulate appetite. Therefore, measuring more of these related adiponectin/leptin variables is recommended in future studies. Another limitation is that exercise plays a different role in obesity and its impact on fat tissue. Therefore, measuring these variables in future studies is recommended.

Conclusion

Based on the results, the expression of the fat gene is mediated by short-term exercise and consuming antioxidant curcumin. Thus, each agent decreases or increases the expression of adiponectin in fat, and both agents increase adiponectin expression and reduce leptin expression in these cells in adipose tissue. The intake of curcumin was consistent across research groups, suggesting that the effect of short-term, aerobic exercise depends on its intensity level and that cells' gene expression changes with that intensity level.

Conflict of Interest

The authors declare no conflicts of interest in the current study, which was conducted at the author's expense.

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