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Original Article

The Effect of Eight-Week Endurance and High-Intensity Interval Training on Leptin, Cortisol and Testosterone Levels in Obese Adolescent Boys

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Abstract

Introduction: Given the critical role of obesity in chronic disease development, establishing effective exercise protocols is essential for managing obesity and regulating energy balance.
Objective: This study aims to investigate the effects of high-intensity endurance and interval training on the hormonal profiles of leptin, cortisol, and testosterone in obese male adolescents.
Methods: This study employed a semi-experimental design with practical implications, utilizing a pre-test and post-test framework alongside a control group. Participants were 50 obese male adolescents who were equally divided into the endurance training group (ET-G), the high-intensity interval training group (HIIT-G), and the control group (C-G). Over an eight-week period, participants engaged in either endurance or HIIT exercises. Blood samples were collected during the pre-test phase after a 14-hour fasting period and again in the post-test phase. Data analysis was conducted using ANCOVA.
Results: The results indicated a significant change in leptin levels ($F=13.574$, $P<0.001$) and a greater increase in testosterone levels ($F=16.947$, $P<0.001$) and in cortisol levels ($F=15.649$, $P<0.001$) from pretest to posttest. Follow-up test showed that HIIT-G experienced a significantly greater reduction in leptin and an increase in testosterone and cortisol levels compared to both ET-G and C-G ($P<0.05$). Additionally, ET-G showed a significantly greater decrease in leptin levels and an increase in testosterone and cortisol levels than C-G ($P<0.05$).
Conclusion: The significant alterations observed in hormone level after interval training, suggest that the HIIT employed in this research is an effective strategy for enhancing metabolism and reducing body fat percentage in obese young men.

Keywords: HIIT, Exercise, Hormones, Obesity, Adolescent

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1. Introduction

Obesity and overweight, along with their associated metabolic disorders, pose a significant global health challenge (1). The World Health Organization reported in 2022 that approximately 1 in 8 individuals worldwide were affected by obesity (2). This issue is particularly alarming among adolescents, driven by factors such as lifestyle changes, urbanization, the intake of high-fat and high-carbohydrate foods, and a lack of physical activity. In 2022, over 390 million children and adolescents aged 5 to 19 were classified as overweight, with 160 million of them living with obesity (3). The increasing prevalence of obesity in this age group raises concerns due to its correlation with chronic diseases, including metabolic syndrome, type 2 diabetes, cardiovascular diseases, cancer, and arthritis (1,4,5).

Obesity is a complex disease influenced by various factors, including genetic predisposition, excessive caloric intake, insufficient physical activity, lifestyle choices, and hormonal fluctuations (6). Each of these elements plays a significant role in the onset and progression of obesity, highlighting the multifaceted nature of this health condition. Cortisol, testosterone, and leptin are key hormones associated with obesity and physical inactivity (7). Leptin is a protein produced by the obesity gene, secreted in a pulsatile manner by adipose tissue into the bloodstream (8). This hormone plays a crucial role in maintaining body weight homeostasis by facilitating communication between fat cells and the central nervous system, particularly the hypothalamic satiety centers. With a molecular weight of 16 kDa, leptin is integral to regulating appetite, hunger, and satiety, acting as a signal for body fat content. Serum leptin levels correlate strongly with body fat percentage and decrease with weight loss, highlighting its importance in energy homeostasis (9). However, abnormal leptin levels can lead to various health issues. Additionally, energy intake influences leptin gene expression, suggesting that variations in diet and physical activity can significantly impact leptin levels. Leptin also plays a crucial role in the central nervous system, particularly within the hypothalamus, where it helps to decrease food intake and enhance energy expenditure (10). This Additionally, serum leptin levels correlate directly with body mass index, and elevated leptin can contribute to increased body weight and fat mass (8,9). Consequently, high leptin levels should not only be regarded as a byproduct of adipose tissue but also as a significant predictor and risk factor for weight gain, along with associated metabolic and cardiovascular diseases.

Testosterone and cortisol are widely recognized as key anabolic and catabolic hormones, respectively, playing crucial roles in the body's adaptation to exercise (11). Both hormones are significantly influenced by obesity, which alters their biosynthesis and metabolism due to the presence of excess adipose tissue and the chronic inflammatory state associated with obesity. Testosterone, an anabolic hormone produced by the gonads, significantly influences the metabolism of various tissues, including muscle. Factors such as inactivity can reduce its production, with some studies indicating a decline in testosterone levels as a consequence of a sedentary lifestyle (12). In contrast, cortisol, produced by the adrenal glands, functions as a catabolic hormone that facilitates the breakdown of proteins, glucose, and lipids, while also regulating blood pressure and immune responses. The interplay between testosterone and cortisol is vital for protein metabolism and lipolysis, making them essential in understanding and managing obesity (11,13). The balance between testosterone and cortisol levels is crucial, as a higher testosterone-to-cortisol ratio is linked to enhanced anabolic processes, while a lower ratio can worsen obesity. Recent research also suggests that elevated cortisol levels may stimulate leptin secretion from adipose tissue, further complicating the hormonal interplay in obesity and inactivity (14). While extensive research has focused on these hormones in lean, untrained men, further studies are needed to explore their roles in obese populations (11,14).

Calorie restriction and dietary management are widely recognized as primary strategies for weight control; however, research indicates that exercise programs focused on reducing fat mass and enhancing cardiorespiratory fitness also contribute significantly to preventing fat accumulation and promoting lean body mass (15). Despite this, many weight loss exercise regimens predominantly advocate for consistent, moderate-intensity endurance training sessions lasting 30 minutes on most days, which often yield minimal reductions in body fat or prove ineffective (16,17). In contrast, interval training, which incorporates rest periods or reduced activity between intense efforts, may offer a more effective alternative by allowing for greater overall work during workouts (18,19). Furthermore, the impact of interval training on weight-regulating hormones and fat metabolism remains an underexplored area in current research (18,20).

Research indicates that high-intensity interval training (HIIT) significantly lowers plasma leptin levels and enhances physical performance in young women compared to continuous training methods (21-23). Additionally, studies have highlighted alterations in plasma leptin, testosterone, and cortisol levels in individuals with obesity, diabetes, and cardiovascular diseases (24,25). While much of the existing literature has focused on endurance sports and their impact on these hormonal levels, there is a notable scarcity of research specifically addressing the effects of high-intensity training. Although many studies report improvements in body composition and hormonal profiles (21,22,24,25), few have explored the implications of moderate and high-intensity interval training. Notably, there is spare research regarding how interval training influences leptin, testosterone, and cortisol levels in obese young adolescents. Given the critical role of obesity in chronic disease development, establishing effective exercise protocols is essential for managing obesity and regulating energy balance. Therefore, this study aims to investigate the effects of high-intensity endurance and interval training on the hormonal profiles of leptin, cortisol, and testosterone in obese male adolescents.

2. Methods

2.1. Participants

This research utilized a semi-experimental design with practical applications, incorporating a pre-test and post-test approach alongside a control group. The study targeted male adolescents aged 15 to 18 who are classified as obese, specifically selecting 75 participants with a body mass index (BMI) at or above the 95th percentile (over 30) after a thorough screening process. These participants were divided into three groups: the endurance training group (ET-G), the high-intensity interval training group (HIIT-G), and the control group (C-G), each consisting of 25 individuals. Prior to the study, both participants and their parents were briefed on the research objectives and methods, discussing the implications of adolescent obesity and the importance of physical activity in its management, with written consent obtained from parents. Each participant underwent a health assessment by a qualified physician, receiving a health certificate and medical clearance for physical activity. Inclusion criteria mandated that participants be obese male adolescents with a BMI at or above the 95th percentile, not using nutritional supplements or following specific diets, free from injuries or illnesses, and without restrictions on high-intensity physical activities. Those who did not meet these criteria were excluded from the study.

2.2. Measurement of Blood Samples

Blood sampling was conducted during the pre-test phase after a 14-hour fasting period and in the post-test phase to mitigate the influence of acute exercise-induced inflammation on the blood markers being studied, particularly leptin. This post-exercise sampling occurred 48 hours after the final exercise session, under controlled laboratory conditions, with 5 cc of blood drawn from the left arm vein of the subjects. To ensure accurate measurement of leptin levels, samples were collected at a consistent time of day to avoid diurnal variations. Following collection, the blood samples were centrifuged for 15 minutes at 3000 rpm to isolate the plasma, which was then frozen at -80°C for subsequent analysis. Serum leptin levels were quantified using radioimmunoassay with the -23100 DSL kit, which has a minimum sensitivity of 0.1 ng/ml. For cortisol and testosterone measurements, the ELISA method was employed, utilizing a kit from Diagnostic Biochem Canada, with sensitivities of 0.4 ng/ml for cortisol and 0.022 ng/ml for testosterone (26).

2.3. Procedure

The research commenced with vital collaboration from the Education Department, which was essential for obtaining the necessary permissions to proceed. Following this, a briefing session was conducted to inform students and their parents about the research goals, methodologies, and the planned intervention. Subsequently, written consent was acquired from the parents. Additionally, anthropometric measurements such as height, weight, and BMI were taken. A high-precision digital scale, manufactured in Germany and accurate to 0.1 kg, was utilized for weight measurement. Subjects were instructed to stand barefoot and in minimal clothing on the scale while maintaining a straight posture, with their weight recorded in kilograms. Height was measured using a height gauge with an accuracy of 0.1 cm, with subjects positioned against a wall to ensure proper alignment of the heel, hip, shoulder, and shoulder blades. The height was recorded in centimeters while the subjects looked straight ahead. BMI was subsequently calculated using the formula weight (in kilograms) divided by the square of height (in meters). Prior to the commencement of the training program, a series of initial assessments were conducted to establish the training intensity under experimental conditions. These assessments included calculating the maximum heart rate using the formula (age - 220), as well as measuring the resting heart rate and heart rate reserve, defined as resting heart rate plus 0.05 times the difference between resting heart rate and maximum heart rate. The participants in the endurance training group engaged in an eight-week program that focused on moderate-intensity aerobic exercise, specifically on a treadmill, targeting 55 to 65% of their maximum heart rate. Training sessions were conducted three times a week, each lasting between 50 to 60 minutes. Initially, the duration started at 30 minutes with an intensity of 55% HRmax, gradually increasing to 60 minutes at 65% HRmax by the program's conclusion. Each session began with a 10-minute warm-up and concluded with a 10-minute cool-down. To ensure optimal performance, the training environment's temperature was regulated to mitigate any potential negative effects. The participants in the high-intensity interval training group engaged in a regimen consisting of 8 to 10 intervals of 4 minutes of running at 80-90% of their heart rate reserve, interspersed with 2-minute active rest periods at 40-50% of heart rate reserve. This training was conducted three times a week, with each session lasting between 50 to 60 minutes. Due to the low aerobic fitness levels of the subjects, the program commenced at an intensity of 60-70% of heart rate reserve during the first week. Every two weeks, the intensity was incrementally increased by 5%, ultimately reaching 80% of heart rate reserve by the end of the 8-week period. Training intensity was monitored using a Polar heart rate monitor. Each session began with approximately 10 minutes of warm-up, which included 4 minutes of slow running, 2 minutes of joint mobility exercises, and 2 to 4 minutes of stretching, followed by a 5-minute cool-down at 40-50% of heart rate reserve (21,22,25). Participants were instructed to avoid any other organized sports activities throughout the 8-week training program. The participants in the control group did not undergo any supplementary interventions.

2.4. Data Analysis

In this study, the research variables were established by calculating the mean and standard deviation (SD). The normality of the data distribution was assessed using the Kolmogorov-Smirnov test, with all results showing P values greater than 0.05. To compare the pretest scores among the different research groups, a one-way analysis of variance (ANOVA) was conducted. Additionally, analysis of covariance (ANCOVA) was used to investigate the differences between groups from the pretest to the posttest. Tukey test was used as post-hoc test. A significance level of 0.05 was maintained for all statistical analyses, which were carried out using SPSS version 27.

3. Results

Table 1 presents the mean and SD of the demographic characteristics of the study participants. The research sample comprised 75 obese male adolescents, aged between 15 and 18 years, recruited from various high schools. These participants were randomly allocated to either the ET-G, HIIT-G or the C-G, with each group containing 25 individuals. The mean ages for the ET-G, HIIT-G or the C-G were 16.88 ± 0.23, 16.89 ± 0.17 and 16.87 ± 0.20 years, respectively, with no statistically significant differences observed (P>0.05). Initial assessments revealed that the BMI of participants in all groups was comparable, again showing no significant differences (P>0.05).

Table 1. Comparison of the Demographic data across Groups.

Variable	ET-G	HIIIT-G	C-G	Comparison
Age (years)	16.88 ± 0.23	16.89 ± 0.17	16.87 ± 0.20	P=0.983
Height (m)	1.70 ± 0.03	1.68 ± 0.03	1.71 ± 0.04	P=0.971
Weight (kg)	88.21 ± 4.56	87.02 ± 3.90	88.74 ± 3.65	P=0.817
BMI	30.50 ± 1.63	30.80 ± 1.48	30.30 ± 1.55	P=0.927

Table 2 and 3 displays the mean and SD for leptin, testosterone and cortisol levels in both the pretest and posttest, alongside the ANCOVA results used to compare the groups. The analysis revealed no significant differences in leptin levels among the groups during the pretest (P>0.05). However, the ANCOVA results indicated a significant change in leptin levels from pretest to posttest (F=13.574, P<0.001). Further analysis using the Tukey test demonstrated that the HIIT-G experienced a significantly greater reduction in leptin levels compared to both the ET-G and the C-G (P<0.05). Additionally, the ET-G showed a significantly greater decrease in leptin levels than the C-G (P<0.05). The analysis indicated no significant differences in testosterone levels among the groups during the pretest (P>0.05). However, ANCOVA results showed a significant change in testosterone levels from pretest to posttest (F=16.947, P<0.001). Subsequent Tukey test analysis revealed that the HIIT-G had a significantly greater increase in testosterone levels compared to both the ET-G and the C-G (P<0.05), while the ET-G also exhibited a significantly greater increase than the C-G ($P<0.05$). Similarly, cortisol levels showed no significant differences among the groups during the pretest ($P>0.05$), but ANCOVA results indicated a significant change from pretest to posttest ($F=15.649$, $P<0.001$). Further analysis with the Tukey test confirmed that the HIIT-G experienced a significantly greater increase in cortisol levels than both the ET-G and the C-G ($P<0.05$), with the ET-G also showing a significantly greater increase than the C-G ($P<0.05$).

Table 2. Baseline Scores across Groups.

Variable		ET-G	HIIIT-G	C-G
Leptin	Pretest	10.23 ± 3.56	10.18 ± 3.41	10.21 ± 3.49
	Posttest	6.25 ± 2.74	8.22 ± 2.93	10.22 ± 3.52
Testosterone	Pretest	5.61 ± 2.65	5.69 ± 2.25	5.63 ± 2.36
	Posttest	10.85 ± 3.39	8.17 ± 3.31	5.60 ± 2.31
Cortisol	Pretest	9.96 ± 2.85	9.87 ± 2.68	9.89 ± 2.74
	Posttest	15.47 ± 4.71	12.65 ± 3.45	9.91 ± 2.86

Table 3. The Results of ANCOVA.

Variable	SS	df	MS	F	P-Value
Leptin	13.648	2	5.468	13.574	<0.001
Testosterone	16.964	2	6.314	16.947	<0.001
Cortisol	14.560	2	5.934	15.649	<0.001

4. Discussion

Given the critical role of obesity in chronic disease development, establishing effective exercise protocols is essential for managing obesity and regulating energy balance. Therefore, this study aims to investigate the effects of high-intensity endurance and interval training on the hormonal profiles of leptin, cortisol, and testosterone in obese male adolescents. The findings reveal that the HIIT-G experienced a significantly greater reduction in leptin levels compared to both the ET-G and the C-G. Additionally, the ET-G showed a significantly greater decrease in leptin levels than the C-G. In addition, the HIIT-G had a significantly greater increase in testosterone and cortisol levels compared to both the ET-G and the C-G, while the ET-G also exhibited a significantly greater increase than the C-G. These findings suggest that HIIT is more effective than endurance training in improving obesity in obese adolescent boys. In contrast, endurance training was found to be beneficial in improving obesity status when compared to a no-training scenario. These findings are in line with those of previous studies (27,28,32,33).

To interpret these findings, it can be sated that interval training is distinguished by its ability to enhance power output in peripheral muscles while simultaneously improving cardiorespiratory capacity, making it a more favorable option compared to endurance training (27,28). In endurance training, the accumulation of blood lactate occurs due to the depletion of phosphocreatine and the utilization of oxygen reserves associated with myoglobin (29). In contrast, the rest intervals incorporated in interval training effectively lower blood lactate levels by replenishing phosphocreatine and myoglobin stores and facilitating lactate clearance (30). This allows interval training to exert maximum stress on peripheral muscles and oxygen transport systems without relying on anaerobic metabolism or leading to lactic acid buildup. Furthermore, the metabolic responses observed during intermittent exercise closely resemble those seen in continuous, moderate-intensity exercise (31). Consequently, it is plausible that the mechanisms influencing leptin levels following interval exercise are akin to those activated by moderate-intensity aerobic activities. Interval exercise may alter nutrient availability and create an energy deficit, thereby engaging metabolic pathways that regulate leptin gene expression, ultimately modulating leptin concentrations by decreasing glucose flow to adipose tissue and its uptake by fat cells (29,30).

Research indicates a notable correlation between decreased plasma leptin levels and enhanced body composition following HIIT compared to traditional endurance training (32,33). Adipose tissue functions as an endocrine organ, releasing pro-inflammatory adipocytokines such as interleukin-6, tumor necrosis factor-α, and leptin (34). In the context of obesity, macrophages within adipose tissue are the primary contributors to inflammatory cytokine production. Factors like elevated fat intake, hypoxia, adipocyte apoptosis, and increased expression of cytokine genes lead to a heightened influx of macrophages into adipose tissue under obese conditions (32). Consequently, an exercise regimen is crucial for modulating adipokine levels, insulin resistance, and inflammation by decreasing adipocyte numbers, enhancing their secretory functions, and reducing macrophage content in adipose tissue. HIIT emerges as a preferred approach for managing body composition, as it helps suppress appetite, promotes the release of corticotropin-releasing factor, and boosts fat oxidation (33,34).

Regarding cortisol and testosterone, the HIIT-G had a significantly greater increase in testosterone and cortisol levels compared to both the ET-G and the C-G, while the ET-G also exhibited a significantly greater increase than the C-G. This aligns with those of previous studies (35-37), which indicated that cortisol and testosterone concentrations increased following interval treadmill running at maximal oxygen consumption compared to an endurance exercise regimen at a lower intensity. The observed increase in cortisol levels in the experimental groups, compared to pre-test values, likely contributed to the absence of significant changes in growth hormone levels. This relationship arises from cortisol's role in inhibiting growth hormone release through the stimulation of somatostatin secretion (35). Intense physical activity activates the hypothalamic-pituitary-adrenal axis, resulting in elevated cortisol production and its subsequent release from carrier proteins, which further elevates cortisol concentrations in the body. In addition, testosterone production is primarily regulated by luteinizing hormone (LH), which is stimulated by physical activity through the hypothalamic-pituitary-gonadal (HPG) axis, leading to increased secretion of gonadotropin-releasing hormone and subsequently LH (36,38). Additionally, testosterone plays a role in reducing leptin levels, a hormone that can inhibit leptin production in adipose tissue (39). Leptin, in turn, can directly suppress the synthesis of sex steroids in the testes by affecting the enzymatic conversion processes and inhibiting key regulatory proteins involved in steroidogenesis. Thus, the observed increase in serum testosterone levels in this study may also be linked to the reduction in leptin levels resulting from the 16 weeks of interval training, which alleviates its inhibitory effects on testosterone production and release.

4.1. Conclusion

The clinical symptoms of various diseases linked to obesity often manifest later in life; however, the roots of conditions like coronary artery disease can be traced back to earlier years. Consequently, addressing obesity during youth is crucial for mitigating the risk of developing metabolic and cardiovascular diseases in adulthood and later life. This study highlights the importance of investigating the impact of exercise and physical activity on fat metabolism and weight management among younger individuals. Nonetheless, it is important to acknowledge certain limitations, including the study's focus on a single sex, which restricts the applicability of findings to female subjects, as well as challenges in controlling participants' dietary intake and psychological factors, particularly during blood sample collection. Despite these limitations, the significant alterations observed in hormone levels—specifically leptin, testosterone, and cortisol after interval training, suggest that the HIIT employed in this research is an effective strategy for enhancing metabolism and reducing body fat percentage in obese young men.

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Footnotes

Authors' Contribution: This study was carried out solely by the corresponding author.

Conflicts of Interest
Non to declare.

Data Availability: The data that support the findings of this study are openly available upon request from the corresponding author.

Ethical Approval: The author confirms that all steps and requirements of this study comply with ethical guidelines. Participants were informed about the characteristics of the study and gave written informed consent.

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