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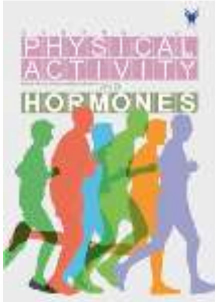

The effect of high-intensity strength and endurance training on cortisol, testosterone, and physical fitness of 15-20-year-old male taekwondo athletes in Rasht

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Abstract

Introduction: High-intensity training changes anthropometric and Biochemical parameters in athletes, so this study aimed to investigate the effect of high-intensity exercise training on physical fitness, plasma cortisol, and testosterone of 15-20-year-old male taekwondo athletes in Rasht.

Material & Methods: This quasi-experimental research was conducted in the 15 to 20-year-old male Taekwondo population of Rasht. The subjects of this study were randomly divided into two experimental (age 17.70±2.26 years), and control (age 16.90±1.72 years) groups. The control group performed the usual taekwondo exercises for 90 minutes along with strength endurance exercises, while the experimental group performed high-intensity exercises (HIE) along with the usual taekwondo exercises for 75 minutes. Before and after 8 weeks of the study period, body mass index (BMI), aerobic and anaerobic power, plasma cortisol, and testosterone were assessed. Dependent and independent t-tests were used to analyze the data of the study. A significance level of less than 0.05 was considered.

Results: The results of this study showed that compared to the pre-test, there was a significant increase in plasma testosterone, aerobic, and anaerobic power in both groups, a decrease in cortisol in the control group, and an increase in plasma adrenaline in the experimental group ($p<0.05$). Comparisons between groups showed a significant increase in plasma adrenaline and anaerobic power in the experimental group ($P < 0.05$).

Conclusion: HIE training in Taekwondo athletes probably has a positive effect on physical fitness factors, cortisol, and testosterone hormones and improves the performance of these athletes.

1. Introduction

Today, different athletes are trying to implement the best training model by changing their training and recovery so that with better training can perform better in competitions. In this regard, examining different types of exercises and observed adaptations can help trainers in designing a suitable training model (1). Taekwondo is one of the Olympic disciplines and is a high-intensity combat sport. The physical fitness of taekwondo athletes reflects their various athletic abilities, and their physical fitness will also have a direct impact on their level of athletic ability (2). The sport includes different high-intensity (1–5 s) aggressive techniques (3). Therefore, it seems that taekwondo athletes need to gain a strong anaerobic capacity, especially in the lower extremities to execute numerous quick and forceful strikes and counterattacks with short rest periods (4).

HIT is often performed as repeated sessions with relatively short to long intermittent activities with full intensity or an intensity close to an intensity equal to or greater than 90% of the maximum oxygen consumption. Depending on the intensity of the exercises, HIT may take from a few seconds to a few minutes. In this case, different periods are separated from each other by a few minutes of rest or low-intensity activity. This training protocol in different forms, in turn, improves the physical performance of athletes (5). On the other hand, the effect on anthropometric parameters such as body fat and fat-free mass (6) and improving the capacity of aerobic and anaerobic systems (7) has been reported in athletes.

Testosterone and cortisol hormones are considered anabolic-catabolic indicators in the performance and effectiveness of sports exercises (8). Testosterone is an anabolic steroid (for tissue building). Testosterone is considered responsible for stimulating the growth of skeletal muscles, increasing the expression of aerobic enzymes, and other processes such as the production of red blood cells (9). Among hormones, cortisol is the main catabolic hormone, with different responses to various exercises. Cortisol is a catabolic hormone secreted by the adrenal gland and plays a great role in metabolism. Studies show that cortisol concentration has a linear relationship to exercise intensity (10). Changes in cortisol secretion have been reported in stressful conditions and sports activities. Despite the change in the secretion of cortisol hormone in certain conditions, testosterone acts as a neutralizing effect of cortisol during physical activity (Gaini et al., 2012). Accordingly, the study of hormone responses to exercise has recently attracted the attention of researchers (11).

The stress response is mediated by the stress system. The main central components of the stress system are the hypothalamic-corticotrophin (pituitary) axis, and the locus caeruleus located in the pons which secretes predominantly norepinephrine (12). The stress responses to exercise may vary greatly, depending on intensity, duration, and type of exercise leading to different levels of allostasis. High-intensity interval exercise (HIIE) refers to short-duration bouts of exercise performed at high intensity (typically above 85% VO2 max), repeated several times after a specific recovery interval (13). There are few published data regarding HIIE and catecholamines. Following high-intensity exercise the elevation of epinephrine and nor-epinephrine is transient and returns to baseline in the first post-exercise hour (14). The greatest ACTH and cortisol elevations are noticed with resistance protocols involving large muscle mass, with moderate to high loads, high total volume, and short rest intervals (15). The type of resistance training may determine whether the HPA axis is stimulated. Fatouros et al. has shown that circuit resistance training, which included 10 exercises for different muscle groups performed one after the other in three consecutive “rounds”, separated by 3 min of rest (total of 30 min), resulted in catecholaminergic, but not HPA axis stimulation and a mild inflammatory reaction (16).

Many researchers have reported changes in biochemical indicators such as blood testosterone and cortisol after exercise (9, 17). Sellami et al showed that acute exercise led to an increase in total testosterone and cortisol levels (11). Adebero et al. observed that men responded to intense multitask exercise with a higher increase in serum cortisol and a lower serum testosterone level than boys (18). During a study of triathlete athletes, 16 sessions of HIT training during two weeks increased the basal concentration of testosterone hormone in the blood serum, but no acute response of cortisol hormone was observed (19). After a bout of high-intensity exercise in 11-year-old athletic boys, it was reported that salivary cortisol increased from 5.55 nmol/L to 15.3 nmol/L in these boys (20). Hamedinia M et al. (2011) did not observe a significant change in cortisol response immediately after moderate and heavy resistance exercise and one hour after exercise (21). Goto and others (2008) reported that resistance training with an intensity of 80% of a maximum repetition does not change the level of cortisol and testosterone (22). However, in the comparison of two resistance training programs with moderate and high intensity, high-intensity training increased the concentration of two hormones. These changes were not observed in delayed responses (23). Kador et al. (2012) reported a significant increase in testosterone after concurrent resistance-endurance training in 10 male athletes. Also, cortisol showed a significant increase after resistance endurance training (24).

Because changes in cortisol and testosterone hormones cause changes in athletes' performance, there are limited findings regarding the effect of high-intensity endurance-strength exercise on testosterone hormones and cortisol. In addition, the information on adolescents' hormone responses to exercise is occasionally conflicting and limited by the participants' age, gender, and level of training. Furthermore, a better understanding of how hormones react to exercise could lead to recommendations for adolescent training that are more appropriate for all age groups. Therefore, the present study was conducted to determine the effect of a period of high-intensity interval training on cortisol, testosterone, and body mass index in Taekwondo boys.

2. Materials and methods

2.1. Participants

The present research was a quasi-experimental study. The statistical population of his research, includes male taekwondo athletes aged 15 to 20 years old in Rasht City that had a professional activity in taekwondo. The selection of the subjects in this research was done by referring to one of the taekwondo clubs. Among the 40 taekwondo volunteers, 20 who were eligible participated in the research. The inclusion criteria included having at least 5 years of Taekwondo training, having a black belt, Lack of damage, doing at least three regular training sessions per week and participation in national competitions. Also, the excluded criteria included injury during training or three sessions of non-participation in training. The samples first participated in an orientation session before starting the research. In this session, while explaining the exercise program, time and duration of its completion, some of the athletes' questions were also answered. In addition, a written consent form was obtained from the samples.

The exercise samples were randomly divided into two equal groups, the control group, which performed moderate-intensity strength-endurance exercises, and the experimental group, which performed high-intensity exercises.

2.2. Exercise protocol

The exercises in two groups included 5 5-minute warm-up and cool-down along with 30 minutes of technical and tactical exercises. The total training duration was 90 for the control group and 75 minutes for the experimental group (HIE).

In the control group (moderate intensity training), 50 minutes of aerobic-strength training including 25 minutes of endurance training with an intensity of 70-80% of the target heart rate (HR) and 25 minutes of strength training with the same intensity of one maximum repetition (1RM) (Table 1). In the experimental group the program of high-intensity training was 35 minutes of aerobic-strength training including 15 minutes of endurance training with an intensity of 80-90% of the target HR and 20 minutes of strength training with the same intensity of 1RM was performed (25, 26). In endurance training, the maximum target HR was calculated based on Karonen's formula and according to the following (27):

Target HR = resting HR + [(percentage of desired intensity) × (maximum HR-resting HR)]

To determine 1RM for each resistance training movement, the 1-RM attempts started from 80% of the self-declared 1-RM, and an additional 5% or less was added until failure. Each attempt was separated by at least 3 min of passive recovery (25).

Endurance training included running and jumping rope, and resistance training also included chest press, squats, front and back lats, front lunges, front arm, back arm, and back thigh.

Table 1. *Exercise Protocol*

	Warm Up	Control Group	Experimental Group HIIT	Technical and Tactical training	Cool down
Time Intensity	5 min	50 min Aerobic-resistance training (70%-80% intensity)	35 min Aerobic-resistance training (85%-90% intensity)	30 min	5 min

2.3. Mesurments

Before and after the training period, 10 ml blood samples were collected from the brachial vein of taekwondo players to measure cortisol and testosterone. The Taekwondo players were told not to eat or drink anything after 10 p.m. The blood samples were taken in the laboratory between 8 a.m. and 9 a.m. Blood samples collected from the subjects were centrifuged for 10 min at 3,000 rpm and kept at −28°C. In serum samples, testosterone, and cortisol were analyzed by autoanalyser (Hitachi, Japan) photometrically, and using a Biosystem kit (BIOSYSTEM, Spain).

A tape measure (Iran) was used to measure height. And to measure the weight of the participants, a standard Beurer scale (Germany) with a sensitivity of 100 grams was used. The subjects' body mass index (BMI) was calculated using height (tape measure, Iran) and weight (Beurer, Germany) measurements and through the following formula (Spielland, 2007).BMI = weight (Kg)/ height (m) 2

Running Anaerobic Sprint Test (RAST) was used to measure anaerobic power. The RAST was applied with the participants performing six 35-m maximal sprints with a 10-second interval between each sprint, and the power in each sprint was then calculated by the formula: Power = (Body Mass × Distance2)/Time3.

A maximal multistage 20-m shuttle running test was used to assess cardiorespiratory fitness. The sample was required to run back and forth on a 20-m course and be on the 20-m line at the same time that a beep was emitted from a tape. The frequency of the sound signal increased in such a way that the running speed started at 8.5 km/h and increased by 0.5 km/ h each minute. The test was terminated when the sample could no longer follow the pace. The result was shown as the number of completed 20-m shuttles. The maximum oxygen consumption (VO2max, mL/ kg −1.min −1) was calculated by the formula: VO2 max = 31.025 + 3.238(S) - 3.248(A) + 0.1536(A•S) where S represents the speed in km/h at the end of the test, and A represents age in years.

2.4. Statistical Analysis

Statistical analysis was performed with the SPSS version 26 program (SPSS Inc., Chicago, IL, USA). Statistical evaluation was done by the Shapiro-Wilk test to examine the normal distribution. We compared differences between the two groups using Student’s paired and independent t-tests. All results were shown as means ± SD in all statistical comparisons P<0.05 was considered as the level of significance.

3. Results

Demographic changes are presented in Table 2.

Table 2. *Demographic Data (n=10 in each group)*

variable	Group	Pre-test	Post-test
Age (year)	Control	17.70±2.26	----
	Experimental	16.90±1.72	----
Height (cm)	Control	169±0.06	----
	Experimental	171±0.09	----
Weight (Kg)	Control	63.85±7.04	64.27±7.67
	Experimental	61.35±11.61	62.60±12.30

According to the statistical results in this study, a decrease in cortisol hormone was observed in both groups, but this decrease was significant only in the moderate-intensity training group (Table 3). Regarding the testosterone hormone, a significant increase was observed in both groups (P = 0.01). On the other hand, moderate and high-intensity exercises caused a significant increase in anaerobic and aerobic power (P = 0.01). However there was no difference between the groups in BMI, cortisol, and testosterone hormones.

Table 3. *paired t-test in control and experimental group (n=10)*

	Group	pre-test M±SD	Post-test M±SD	Sig
BMI (kg/ m^2)	Control	22.16±1.66	22.30±1.88	0.20
	Experimental	20.68±2.74	21.12±3.13	0.061
Cortisol(µg /dl)	Control	14.27±3.12	12.97±3.48	0.04*
	Experimental	13.85±2.77	11.78±2.76	0.10
Testosterone (ng /dl)	Control	7.34±2.73	8.85±2.73	0.01*
	Experimental	7.27±1.83	8.30±2.30	0.01*
Adrenalin (pg/ml)	Control	2.30±1.62	2.64±1.52	.41
	Experimental	2.69±2.63	4.97±2	.01*
Anaerobic power (W)	Control	466±15.77±00	491±17.28	0.01*
	Experimental	467±14.94±00	554±10.74±00	0.01*
Aerobic power	Control	69.02±8.74	77.84±9.71	.01*

($mg.kg^{-1}.min^{-1}$)	Experimental	65.42±10.61	75.85±8.56	.01*

*Significant at the 5% level

According to the statistical independent t- test results presented in Table 3, in comparison between the groups, the level of cortisol and testosterone hormones showed that there is no significant difference between them. But in the experimental group, a significant increase in the plasma level of adrenaline was observed. Anaerobic power also increased significantly in the experimental group.

Table 4. *Independent t-test in control and experimental group (n=10)*

Variable	difference between means	F	t	df	sig
BMI (kg/ m^2)	-0.29	2.57	-1.14	18	0.15
Cortisol(μg /dl)	-2.23	2.11	-1.51	18	0.14
Testosterone (ng /dl)	0.48	1.52	0.90	18	0.38
Adrenalin(pg/ml)	-1.89	2.29	-2.33	18	0.03*
Anaerobic power (W)	-62.00	4.93	-9/99	18	0.01*
Aerobic power ($mg.kg^{-1}.min^{-1}$)	2.61	2.64	1.31	18	0.20

*Significant at the 5% level

4. Discussion

In the present study, we examined the effect of high-intensity endurance and strength training on male taekwondo players aged 15 to 20. A significant increase in plasma testosterone, aerobic and anaerobic power was observed in both groups in the post-test compared to the pre-test, but a decrease in cortisol hormone was significantly observed only in the moderate-intensity training group. The results of this research showed that high-intensity exercise training increases plasma levels of adrenaline, and anaerobic power significantly compared to moderate exercise training.

The decrease in the amount of cortisol hormone in the moderate-intensity training group was consistent with the results of Copeland et al., 2002, Kong et al., 2015. Copeland et al observed a significant decrease in cortisol levels in 30 healthy women aged 16 to 69 years with resistance and endurance training (28). In addition, this reduction was observed in women aged 18 to 30 years following intense and moderate interval training (29). However many researchers, including Mohammadi et al., 2015: Kramer et al., 2008) reported an increase in this hormone following moderate to high-intensity exercise (17, 30). Of course, the lack of change of this hormone after exercise has also been reported by Fadaei et al. (2023) (31). Reeves et al. (2006) stated that performing resistance training with an intensity of 70% of a maximum repetition does not cause a significant change in blood cortisol (32). Sinaii et al. (2010) showed that after a bout of intense swimming training, although compared to baseline values, plasma cortisol levels showed an upward trend immediately after exercise and during the period of returning to the initial state (33), this difference was statistically significant did not have. Goto et al. (2008) reported that resistance exercise with an intensity of 80% of a maximum repetition does not change the cortisol level (22). West and others also stated that performing a forearm exercise with 95% intensity of 10 repetitions did not significantly change blood cortisol levels. A plausible explanation for these discrepancies among previous studies may be related to the type of exercise, measurement methods, exercise intensity, and age (34). The direct effect of cortisol is through the stimulation of DNA, which leads to the formation of mRNA and ultimately protein synthesis, which is a slow process. Cortisol, like thyroxine, has a facilitating effect on the mobilization of nutrients during exercise, which allows other fast-acting hormones such as epinephrine and glucagon to mobilize glucose and free fatty acid. In the present study, high and medium-intensity interval training caused an increase of 17 and 12% respectively in the amount of testosterone hormone in the blood of taekwondo boys. Most of the studies confirmed the increase in testosterone levels after endurance and resistance exercise (22, 30, 31, 35).

Wegner et al. showed an acute increase in testosterone concentration immediately after the maximal test time in adults and adolescents (36). The increase in testosterone largely depends on the load and intensity of the training, the muscle mass involved, and the fitness level of the athlete (36). Fadaei et al investigated the effect of acute intense exercise on the hormonal response in male, adolescent, and youth soccer players, and the results showed that these exercises increased testosterone in the young group compared to children and adolescents (31). In adults, intense exercise increases circulating testosterone concentrations (37). They stated that there is an increase in sympathetic function due to exercise that may lead to a faster testosterone response (38). This is even though no significant change in blood testosterone concentration has been reported after a period of endurance training with moderate intensity (39). Also, 16 sessions of HIT training during two weeks increased the baseline concentration of blood testosterone in male athletes. Even two weeks of short-term HIT training could cause an acute anabolic state and have positive effects on the athlete. Khosravi et al. showed that the order of intense resistance and endurance exercises does not affect the response of cortisol, testosterone, insulin, and insulin-like growth factor (IGF-1) in athletes women (40). The increase in the concentration of testosterone hormone due to intense intermittent exercise and its positive effects can be explained by the ability of testosterone to stimulate the production of red blood cells, increase hemoglobin and blood hematocrit levels, and possibly increase tolerance and lactate carrying capacity (19). The amount of muscle mass involved in the activity, the intensity and volume of training, the food consumed, age, and training experience are factors affecting the response of the testosterone hormone (41). Intense training protocols that involve large muscles and several joints cause an acute increase in testosterone concentrations (42). Also, the increase in testosterone in some research may be due to adrenalin stimulation, or the ability to adjust testosterone secretion (42, 43).

In line with the current research, Liu et al. (2023) investigated the effect of high-intensity training on the performance of taekwondo athletes, which showed that this training improved aerobic and anaerobic capacity (2). Melhim and others (2001) also reported that a training program increased the anaerobic power and anaerobic capacity of taekwondo athletes by 28 and 61.5 percent, respectively (44). The effect of HIT exercises on the anaerobic capacity of athletes has been stated in many studies (19). Markovic et al. (2005) showed that successful taekwondo athletes have higher speed and anaerobic thresholds than less successful taekwondo athletes (45). Considering that the nature of Taekwondo athletes requires sudden, fast movements and powerful blows, this issue causes the profile of the energetic system and their physiological characteristics towards the anaerobic system and powerful functions, and the speed should be changed and the athletes of this field do not find an aerobic profile. Of course, the aerobic fitness of taekwondo athletes should also be at a high level so that they can return to the appropriate initial state during repeated efforts between competition periods and repeated training that they do in one day.

5. Conclusion

It seems that aerobic and resistance exercises with high intensity (HIE) are effective on the anaerobic power and adrenaline levels of taekwondo athletes. Although there was a change in the cortisol variable, it was not statistically significant. Considering the limitations of this research, such as the small number of samples and the low age of the athletes, the need for more research in different ages, a higher number of subjects, and different degrees of professionalism of the subjects is felt. Also, in the design of future research, it is better to consider different timings for blood index measurements.

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Conflict of interests: The authors declare no conflicts of interest.

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