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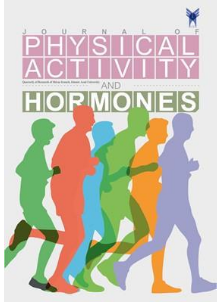


# The Effects of high-intensity Resistance-Endurance Training on Physical Fitness, Levels of serum Cortisol, Testosterone, and insulin-like growth factor1 (IGF1) among Adolescent Taekwondo players

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## Abstract

**Introduction:** Strength and endurance training has experienced a surge in popularity in recent years and is currently one of the most commonly practiced training methods. This study investigated the effects of high-intensity resistance, and endurance training on physical fitness and levels of serum cortisol, testosterone, and insulin-like growth factor1 (IGF1) among adolescent athletes' taekwondo players.

**Material & Methods:** This quasi-experimental study was based on the pre and post-test design with a control group. The first group engaged in moderate-intensity resistance endurance training along with regular taekwondo training (CG). CG performed a total of 95 minutes of training, including warm-up, cool-down, technical and tactical exercises, 50 minutes of moderate-intensity resistance (60-70% of one repetition maximum; 1RM), and endurance (60-70% of target heart rate; THR) training. During this time, the experimental group (EG) performed a total of 80 minutes of the same training, except that they performed high-intensity resistance (70-80% of 1RM) and endurance (70-80% of THR) training for 35 minutes. Participants included 20 male taekwondo players who were randomly assigned to two equal EG and CG groups with more than two years of training experience. They were evaluated for age, height, weight, and some physical fitness parameters such as aerobic capacity (shuttle run test) and anaerobic capacity (RAST test). CG performed conventional moderate-intensity strength and endurance exercises; the EG performed these exercises at high-intensity training for 80 minutes. The variables were measured before and after 8 weeks of training. Moreover, 10 ml of blood was taken from the arm vein of participants both before and after the study to measure the levels of cortisol, testosterone, and IgF1.

**Results:** Results showed a significant increase in the cortisol level and anaerobic capacity in both CG and EG ($p<0.05$). In addition, the resting metabolic rate (RMR) increased in the EG, and cortisol level decreased in the CG ($p<0.05$), but aerobic capacity was promot in both groups ($p<0.05$). In the comparison between groups, only anaerobic capacity increased significantly in the experimental group, and no significant differences were observed in other variables.

**Conclusion:** Considering the positive effects of high-intensity aerobic and resistance training on both aerobic and anaerobic power, it is recommended that taekwondo coaches incorporate these exercises into their athletes' training programs. However, further studies are needed to confirm the effects of these exercises on hormonal and bioenergetic changes in the body. The findings underscore the importance of tailored training regimens that consider individual athlete needs and the specific demands of taekwondo.

## 1. Introduction

Taekwondo (TKD) is a martial art characterized by techniques including kicking, blocking, and punching for offensive or defensive purposes. This sport is an explosive activity requiring athletes to execute various striking techniques with high levels of energy, muscular strength, endurance, flexibility, speed, and agility (1, 2).

Muscle strength enhancement positively influences the rate of force development, thereby improving jumping, sprinting, and agility (3, 4). Strength training aims to enhance an athlete's strength, power, muscular endurance, and muscle hypertrophy. These adaptations may manifest both neurologically and physiologically (5, 6). Resistance training enhances strength and power while mitigating injury risk, serving as a crucial supplementary training modality for elite, amateur (7), young (8), and old (9) athletes, as well as athletes participating in individual (10) and group (11) sports. Moreover, resistance training is regarded as a fundamental training modality in sports such as bodybuilding, weightlifting, powerlifting, and CrossFit (12, 13). Resistance training causes the release of anabolic hormones such as testosterone and growth hormone, and in return, endurance training helps reduce cortisol levels, which is a stress-related hormone. The combination of these two types of training not only improves sports performance but also has positive effects on people's mental health and quality of life (14). By examining the acute and chronic physiological changes of the endocrine system, it was evaluated how nutrition, age, sex, and exercise program can affect the physiological adaptation caused by strength training

By examining the acute and chronic physiological changes of the endocrine system, it was evaluated how nutrition, age, sex, and exercise programs can affect the physiological adaptation caused by strength training. Hormonal surges induced by strength training manifest in four primary ways: acute adaptations during and after exercise; chronic and acute alterations in the training stimulus; improvement in muscle receptors, and chronic alterations in resting levels (6, 15).

Testosterone and GH are both anabolic hormones that increase protein synthesis and prevent protein degradation in muscles (16). Testosterone is produced through the secretion of luteinizing hormone by the anterior pituitary gland. Luteinizing hormone activates Leydig cells to synthesize testosterone. GH is released by the anterior pituitary gland and facilitates protein synthesis in muscles (15, 17). Serum-free testosterone concentrations in both men and women are markedly elevated following a course of resistance training (18, 19). Various components of resistance training can amplify acute responses in testosterone levels. The highest increase in testosterone levels occurs during exercises that engage large muscle groups, such as Olympic lifts that include cleans, squats, and deadlifts. Other factors included high volume and intensity along with short rest periods (20). Testosterone levels peak approximately 15 minutes after exercise and revert to baseline within 1 hour (21).

As a catabolic hormone, cortisol is the principal glucocorticoid hormone (22). Cortisol is synthesized by the adrenal cortex and constitutes 95% of total glucocorticoid activity. Cortisol influences the metabolism of various sources of energy, including glucose, protein, and free fatty acids. Cortisol facilitates the catabolism of proteins into amino acids and promotes growth hormone activity. If cortisol remains unregulated, it may inhibit protein synthesis and lead to protein degradation (23, 24).

The cortisol level follows a circadian rhythm marked by elevated levels upon awakening, a rapid decrease 30-45 minutes thereafter, and a gradual decline until bedtime (25). Brunsden (24) showed that resistance training significantly increases acute cortisol levels, especially in exercise regimens that concurrently enhance testosterone and GH. The highest increase in serum cortisol levels is observed after high-intensity exercise programs with short rest intervals. Additionally, concurrent training increases cortisol levels more significantly than strength training alone, as physical stress is correlated with an increase in this hormone. Nevertheless, men's cortisol levels experience a decline after 8 weeks of training and revert to their baseline levels after 16 weeks.

Strength training significantly elevates acute levels of GH, with this elevation contingent upon variables including exercise protocol, muscle mass, and overall training volume. Moreover, increasing the volume and intensity of exercises, minimizing rest intervals, and employing multiple sets (supersets) rather than single sets significantly contribute to this elevation. Studies have demonstrated that rest intervals of 30 to 60 seconds between sets can effectively increase the GH level (26). The testosterone-to-cortisol concentration ratio (T/C) serves as an indicator of exercise-induced stress levels. Variations in the levels of these hormones are responsible for regulating numerous exercise-induced responses, such as hypertrophy and enhanced strength (27, 28). Brief rest intervals combined with heightened intensity and volume of exercises can increase lactate levels in the blood. The increased blood lactate concentration results in a heightened acute level of GH. The increased H+ ions generated from lactic acid have been proposed as the primary mechanism of GH secretion (28) Hormonal adaptations resulting from exercise training in children and adolescents markedly differ from those in adults, likely due to varying stages of maturation (29). High intensity strength and endurance training in athletes can potentially lead to significant reduction in subcutaneous fat. Decreased serum leptin and glucose levels and improved insulin sensitivity can improve the taekwondo player’s performance (30). Given the lack of evidence regarding the effects of high-intensity training in adolescents and young adults, this study sought to determine the effect of a high-intensity strength-endurance training on physical fitness and levels of serum cortisol, testosterone, and insulin-like growth factor1 (IGF1) among adolescent athletes’ taekwondo players.

## 2. Methodology

### 2.1. Materials and methods

This was a quasi-experimental study based on a pretest-posttest design that was conducted in Rasht, Iran. The control group (CG) performed a total of 95 minutes of training, including warm-up, cool-down, technical and tactical exercises, 50 minutes of moderate-intensity resistance(60-70% of one repetition maximum; 1RM), and endurance (60-70% of target heart rate; THR) training. During this time, the experimental group (EG) performed a total of 80 minutes of the same training, except that they performed high-intensity resistance (70-80% of 1RM) and endurance (70-80% of THR) training for 35 minutes.

### 2.2. Participants

The participants included 20 male taekwondo players who were randomly selected from 40 healthy athletes (with no injury) aged 15-20 years with more than two years of experience in taekwondo training. All participants filled out a specialized questionnaire on physical activity level and provided their medical records before entering the study; written consent forms were obtained from all participants. The exclusion criteria were injury during the training sessions and absence in more than three consequent sessions. After the general health of participants was ensured, they were invited to a laboratory to brief them on the research objectives and procedures. Participants were randomly assigned to the CG (regular moderate-intensity training group) and EG (high-intensity resistance and endurance training).

### 2.3. Measurements

Participants were evaluated for age, height, weight, and some physical fitness parameters such as aerobic capacity (shuttle run test) and anaerobic capacity (Running-Based Anaerobic Sprint Test; RAST).

**Shuttle run test:** The test is an incremental intermittent running test between two separate lines at a distance of 20 m(31). The initial speed, marked by acoustic signals, is 8.5 km/h, increasing by 0.5 km/h every minute; so, the time that the participants have to cover the distance of 20 m decreases over time until the participant can no longer reach the designated speed (31). $VO_{2max}$ estimations were based on regression equations, established by Leger et al. The formula used for this calculator is the last stage number used to predict maximal oxygen uptake (VO2max, $ml.kg^{-1}.min^{-1}$) from the speed (X, $km.hr^{-1}$) corresponding to that stage (speed = 8 + 0.5 x stage no.) and age (A, years): $VO_{2max}$ ($ml.kg^{-1}.min^{-1}$) = 31.025 + 3.238X - 3.248A + 0.1536AX

This formula is suitable for boys and girls aged 8-19 years. For adults, similar measurements indicated that the same equation could be used keeping the age constant at 18.

**Running-Based Anaerobic Sprint Test; RAST:** RAST is a testing protocol designed to measure anaerobic power and capacity. The test involves six sprints over a 35-metre distance, with a 10-second recovery between each sprint. The formula for calculating Peak Power Output (PPO) is:

*PPO = Body mass * Distance ² ÷ Time ³*

*Anaerobic capacity (AC) is the total work completed during the test duration.*

*AC = Sum of all six sprint PPOs(32)*

**Resting metabolism raten(RMR):** To measure resting metabolic rate (RMR), using an indirect consumption calculation method that involves assessing carbon dioxide consumption and production at rest (33). The Harris-Benedict formula for calculating RMR in men is as follows:

*RMR=66.47+ (13.75 × body mass in kg) + (5.003×height, in cm) − (6. 775×age, in years)(34).*

**Laboratory tests:** 10 ml of blood was taken from the brachial vein of participants both before and after the study to measure the levels of cortisol, testosterone, and IGF1. To prevent blood clotting, the samples were immediately transferred into FL tubes (Italy). Then they were centrifuged (Orom Tajhiz) at 3,000 rpm for 5 minutes to separate the plasma; finally, the samples were kept at -20℃ until the end of the study. Testosterone and cortisol levels were assessed utilizing the Roche kit (Germany) and with the use of the electro-chemiluminescence (ECL) technique.

### 2.4. Intervention

The training program for teenage taekwondo athletes consisted of 3 weekly training sessions for 8 weeks. Each training session included a 10-minute warm-up with stretching and light jogging, and 5 minute cool-down (stretching and deep breathing). It was accompanied by 30 minutes of technical and tactical training. The control group performed 50 minutes of moderate-intensity strength (25 minutes with 60% - 70% one Repetition maximum), which included basic movements such as squats, chest presses, deadlifts, and leg presses, with 3 sets of 10 repetitions, and endurance (25 minutes with 60% - 70% target heart rate) training. The target heart rate was calculated using the Karvenon formula (Target HR = ((Maximum HR − Resting HR) × Intensity %) + Resting HR. Attention to correct form and sufficient rest between sets (60-90 seconds) were important points of this program. The experimental group performed 35 minutes of intense resistance endurance training. They performed 35 minutes of aerobic-strength training, including 15 minutes of endurance training at an intensity of 70-80% of target heart rate and 20 minutes of strength training at an intensity of 70-80% of one repetition maximum (1RM).

### 2.5. Statistical Methods

The normal distribution of the data obtained was examined using the Shapiro-wilk test. The independent t-test was then employed to compare the CG and EG in terms of the data that followed a normal distribution pattern. All statistical tests were performed in SPSS version 23 at a significance level of 0.05.

## 3. Results

Table 1 Shows the individual characters of the groups. The results showed that in the CG (age 17.70 ± 2.26 years, weight 63.85 ± 7.04 kg), and EG (age 16.9 ± 1.7 years, weight 61.35 ± 11.61 kg). The values are presented in the table.

***Table 1.*** *Individual characteristics of participants*

| | | Pre-test | Post- test |
|---|---|---|---|
| **Parameter** | Group | Mean ± SD | Mean ± SD |
| **Age (years)** | CG | 17.70±2.26 | --- |
| | EG | 16.9±1.72 | --- |
| **Height (cm)** | CG | 169±0.06 | --- |
| | EG | 171±0.09 | --- |
| **Weight (kg)** | CG | 63.85±7.04 | 64.27±7.67 |
| | EG | 61.35±11.61 | 62.60±12.30 |

CG: control group; EG: Experimental group

The paired t-test results indicated the significant effects of training intervention on the physiological parameters of the participants. The participants in the EG showed a significant promotion in RMR and testosterone levels ($p<0.05$), whereas these parameters demonstrated no significant change in the CG. The significant increase in cortisol levels in the CG ($p<0.01$). The data revealed no significant change in GH in either of the groups. Furthermore, both groups exhibited a significant reduction in aerobic and anaerobic capacity ($p<0.01$), which can be attributed to the influence of exercise training. These results suggest that exercise training can improve some physiological indicators and positively affect general health (Table 2).

***Table 2.*** *Results of the paired t-test comparing the situation before and after the intervention in the control group (CG) and the EG (n=10 in each group)*

| Parameter | Group | Mean ± SE (Pre-test) | Mean ± SE (Post-test) | Mean difference | SEM | t-value | df | Sig. |
|---|---|---|---|---|---|---|---|---|
| RMR | CG | 1198.15±41.60 | 1199.55±43.31 | -1.39 | 1.01 | -1.37 | 9 | 0.20 |
| | EG | 1200.48±67.44 | 1204.85±68.07 | -4.36 | 1.74 | -2.50 | 9 | 0.03* |
| Testosterone (ng/ml) | CG | 7.34±2.73 | 8.85±2.73 | -1.39 | 0.59 | -4.03 | 9 | 0.01* |
| | EG | 7.27±1.83 | 8.30±2.30 | -1.03 | 0.3 | -3.15 | 9 | 0.01* |
| Cortisol (μg/dL) | CG | 17.27±3.12 | 12.97±3.48 | 4.30 | 0.92 | 4.67 | 9 | 0.01* |
| | EG | 13.85±2.77 | 11.78±2.67 | 2.07 | 1.15 | -1.79 | 9 | 0.1 |
| IGF1 (ng/ml) | CG | 6.55±3.04 | 5.72±21.82 | 1.60 | 45.77 | -0.31 | 9 | 0.75 |
| | EG | 13.85±2.77 | 11.78±2.76 | 2.07 | 1.15 | -1.79 | 9 | 0.10 |
| Aerobic capacity (ml/kg/min) | CG | 57.84±9.71 | 59.02±8.74 | 2.32 | 0.86 | 10.33 | 9 | 0.04* |
| | EG | 56.85±8.56 | 61.42±10.61 | 5.43 | 1.78 | 6.40 | 9 | 0.03* |
| Anaerobic capacity (wat) | CG | 466±15.77 | 491±17.28 | -24.2 | 3.07 | -8.13 | 9 | 0.04* |
| | EG | 467±14.94 | 544±10.74 | -77.87 | 5.35 | -16.15 | 9 | 0.01* |

* Significant level at pretest and posttest; CG: control group; EG: Experimental group; RMR, Resting Metabolic Test

The study results also indicated that RMR and testosterone levels increased significantly in both groups. In addition, the cortisol level showed a significant reduction in the CG, but this reduction was not observed in the EG. On the other hand, aerobic capacity significantly increased in both groups, but no significant difference was observed between the two groups. However, compared to the control group, only anaerobic power increased significantly in the experimental group. (Table 3). No significant differences were observed between the groups in other variables.

***Table 3.*** *Results of independent t-test comparing post-test between control group (10 subjects) and exercise group*

| | Mean difference | F | t | df | Sig. |
|---|---|---|---|---|---|
| RMR | -2.97 | 2.57 | -1.47 | 18 | .15 |
| Testosterone (ng/ml) | .48 | 1.52 | .9 | 18 | .38 |
| Cortisol (μg/dL) | -2.23 | 2.11 | -1.51 | 18 | .12 |
| IgF1 (ng/ml) | 16.70 | 3.96 | .3 | 18 | .76 |
| Aerobic capacity (ml/kg/min) | 2.61 | 2.64 | 1.31 | 18 | 0.20 |
| Anaerobic capacity (wat) | -62.00 | 4.93 | -9.99 | 18 | 0.01 * |

## 4. Discussion

The study results indicated that high-intensity resistance-strength training significantly increased the resting metabolic rate (RMR) in male taekwondo players, although there was no significant difference between two groups. This aligned with Sirithienthad (2006), who reported a 10% increase in RMR within 21 hours after resistance exercises. Additionally, Potteiger et al. (2008) demonstrated that RMR significantly increased following 16 months of aerobic training, supporting the notion that consistent training positively impacts metabolic rates. Furthermore, Nouri et al. (2012) reported a significant increase in RMR in the resistance training group, suggesting that resistance training can effectively boost metabolic efficiency among athletes. The findings suggest that the type and intensity of exercises play a crucial role in influencing RMR. Factors such as heredity, body size, age, gender, and diet also significantly affect RMR, indicating a complex interplay between various elements that influence metabolic rates.

Conversely, several studies present contradictory results regarding RMR. Haghighi et al. (2013) found that resistance training at 75% of maximum repetition did not significantly change RMR(38), and Hunter et al. (2006) reported that 40 minutes of high-intensity resistance training failed to alter resting energy expenditure (REE) (39). Antunes et al. (2005) further demonstrated a significant reduction in RMR after six months of aerobic training, along with declines in thyroid hormones T3 and T4, which may contribute to decreased RMR(41). These inconsistencies highlight the need for further research to clarify the effects of different training modalities on RMR. Changes in RMR are less influenced by physical activity in athletes compared to sedentary individuals, suggesting that regular exercise may lead to a more stable metabolic rate. Moreover, aerobic exercise has been shown to reduce plasma thyroxine levels, potentially leading to decreased RMR (37).

The investigation into cortisol levels revealed a significant reduction in the control group, but no significant difference between the EG and CG. This finding is consistent with previous studies that reported mixed results regarding exercise's effects on cortisol. For example, (42). Soheili et al. (2024) noted a significant increase in cortisol following moderate-intensity endurance training, while Farzanaki et al. (2008) documented increased cortisol concentrations with higher exercise intensities (43). Kraemer et al. (2008) found similar results in marathon cycling races (44), whereas Reeves et al. (2006) showed no significant change in cortisol levels with resistance training at 70% of maximum repetition (45). These discrepancies highlight that exercise intensity and duration are critical factors influencing cortisol secretion. Intense physical activity can elevate ACTH secretion, leading to increased cortisol levels (39). Sebghati Shiraz et al. in their study, revealed that both sprint and small-size game training individually can have desirable effects on testosterone, cortisol, and T/C ratio in teenage soccer players(46).

The results indicated a significant increase in testosterone levels in both groups following high-intensity resistance and endurance training, but no significant difference between the groups. This finding aligns with previous studies, such as Jabloo et al. (2012), which reported significant changes in testosterone levels after similar training protocols (47). However, West et al. (2009) and Reeves et al. (2006) found no significant changes in testosterone levels under specific training conditions, indicating that various factors—including exercise duration, muscle activity intensity, and individual characteristics—affect hormonal responses. Rigorous training targeting large muscle groups can lead to acute elevations in testosterone, possibly due to adrenaline stimulation and the effects of lactate (49). and his colleagues pointed out that high-intensity training in Taekwondo athletes probably has a positive effect on physical fitness factors, cortisol, and testosterone hormones and improves the performance of these athletes (50).

Investigating IGF-1 levels revealed no significant differences within or between groups. Previous studies, including Irwin et al. (2009), noted a decrease in IGF-1 following moderate-intensity aerobic activities (51). Hasani-Ranjbar et al. (2012) documented an elevation in IGF-1 after rigorous resistance training, suggesting that the type and intensity of exercise significantly influence IGF-1 responses (52). The mechanisms governing IGF-1 secretion involve growth hormone-releasing hormone (GHRH), which stimulates GH secretion and subsequently promotes IGF-1 synthesis in the liver. Various factors, including training type, intensity, and duration, impact IGF-1 levels. Babaei et al.

showed that serum testosterone levels may increase slightly after high-intensity strength training and then high-intensity aerobic training. Serum cortisol levels decrease after high-intensity aerobic training but increase after high-intensity strength training, and it is possible that insulin-like growth factor-1 (Igf1) serum levels decrease after high-intensity strength training(53).

The study findings indicated a significant reduction in aerobic capacity in both groups, while only the CG exhibited a significant increase in anaerobic capacity. This highlights the varying effects of exercise protocols on bioenergetics indicators. Marković et al. (2005) noted that successful taekwondo athletes have higher speed and anaerobic thresholds (54). Melhim et al. (2001) reported that taekwondo training improved anaerobic capacity but did not affect aerobic capacity (55). The demands of taekwondo, characterized by rapid movements and powerful kicks, necessitate a focus on anaerobic capabilities. However, enhancing aerobic fitness is essential for adequate recovery between training sessions and competition intervals (56-58). Contrastingly, Chara et al. (2005) found improvements in maximal oxygen consumption after simultaneous resistance and endurance training in non-athletic men. Nouri et al. (2013) confirmed the positive effects of exercise training on VO2 max (37). However, Murtag et al. (2005) concluded that physical activity had no significant effect on aerobic capacity (59). These discrepancies may stem from variations in baseline VO2max, exercise intensity, and monitoring methods during training (60).

This study faces several limitations, including a small sample size that may affect the generalizability of the results and a lack of control over environmental factors that can influence athletic performance and hormonal responses. Additionally, the absence of psychological impact assessments and the lack of studies on female athletes are notable limitations. To improve future research, it is suggested that studies be conducted with larger sample sizes and standardized training protocols. Furthermore, the simultaneous effects of resistance and aerobic training, as well as the role of diet and supplements, should be investigated. Utilizing advanced technologies for more accurate measurement of hormonal and metabolic changes, along with designing long-term studies, could enhance our understanding of the sustained effects of training on metabolism and hormones.

The findings of this research indicate that high-intensity resistance and strength training significantly enhance the resting metabolic rate (RMR) among male taekwondo players, although no significant differences were observed between the test and control groups. These results align with previous studies that suggest resistance training positively impacts metabolic efficiency. Additionally, while cortisol levels decreased in the CG, no significant changes were found in the EG, highlighting the complex relationship between exercise intensity and hormonal responses. Overall, the study underscores the importance of exercise type and intensity in influencing metabolic rates and hormonal balances, while also identifying the need for further research to clarify these relationships and their implications for athletic performance.

## 5. Conclusion

In conclusion, the research contributes valuable insights into the effects of high intensity aerobic resistance training can affect metabolic and hormonal responses in male taekwondo players, emphasizing the need for standardized protocols and larger sample sizes in future studies to enhance understanding in this field.

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