Hormonal responses to taekwondo fighting simulation versus conventional resistance exercise in young elite taekwondo athletes

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A Study Design
B Data Collection
C Statistical Analysis
D Manuscript Preparation
E Funds Collection

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Abstract

Background and Study Aim: Taekwondo, including martial art competitions, involve explosive and quick movements of the lower extremities and thus, require a high contribution of the anaerobic energy system. Previous findings indicate preferential use of anaerobic or lactic acid system in taekwondo including martial art competitions. The aim of this study was the knowledge about hormonal such as insulin-like growth factor 1 (IGF-1), testosterone and cortisol responses between taekwondo fighting simulation (TFS) and traditional resistance exercise (RE) in elite taekwondo athletes.

Material and Methods: Eight Korea Armed Forces Athletic Corps taekwondo athletes participated in our randomized cross-over study, during three separate visits by a period of 7 days. Visit 1: measured of 1 repetition-maximum and given informed; visit 2 and visit 3: 1) 2 sets of 8-reptition maximum each of squat, hip-abduction and leg-extension exercises or 2) a TFS similar to a real taekwondo match consisting of 3 rounds of 2 minutes were undertaken by the participants. Blood samples were taken to determine insulin-like growth factor 1 (IGF-1), testosterone and cortisol concentrations during pre exercise, immediate post exercise, and 15 minutes post exercise.

Results: IGF-1 concentration was greater at immediate post-exercise than pre exercise ($p = 0.02$) and post-15m ($p = 0.003$) after TFS, but any significant change was not detected after RE. Cortisol concentration was lower at immediate post-exercise than pre- ($p = 0.006$) and at post-15m than pre- ($p = 0.014$) after RE, but any significant change was not detected after TFS. Testosterone concentration was greater at immediate post exercise than pre- ($p = 0.003$) and reduced at post-15 minutes than immediate post exercise ($p = 0.002$) in the both type of exercise.

Conclusion: Taekwondo competition affects hormonal response is similar to after resistance training in elite taekwondo athletes. Future studies are required to compare the hormonal responses by setting the same energy consumption of TFS and RE. It is also important to study the differences in hormone changes with respect to physical abilities of individuals.

Keywords: 1RM • hypertrophy • muscular strength • power • training load

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Taekwondo – *noun* is a combat sport and was developed during the 1940s and 1950s by Korean martial artists**.**

Hormone – *noun* a substance that is produced by one part of the body, especially the endocrine glands, and is carried to another part of the body by the bloodstream where it has particular effects or functions [35].

Crossover study – *noun* in a randomized clinical trial, the subjects are randomly assigned to different arms of the study which receive different treatments.

1RM – individual's maximal strength or 1 repetition maximum [36].

Exercise – noun 1. physical or mental activity, especially the active use of the muscles as a way of keeping fit, correcting a deformity or strengthening a part 2. a particular movement or action designed to use and strengthen the muscles • *verb* **1**. to undertake physical exercise in order to keep fit and healthy 2. to subject the body, or part of it, to repetitive physical exertion or energetic movement in order to strengthen it or improve its condition [35].

Resistance training –*noun* training that increases muscle strength by working against resistance such as a weighted dumbbell or barbell [35].

Muscular strength – maximal force or tension level produced by a muscle or muscle group [37].

Power – noun 1. physical force or strength **2.** the ability, strength, and capacity to do something [35].

Hypertrophy – *noun* an increase in the number or size of cells in a tissue [35].

Endurance – *noun* the ability or power to bear prolonged exertion, pain or hardship endurance athlete [35].

INTRODUCTION

Taekwondo, including martial art competitions, involve explosive and quick movements of the lower extremities and thus, require a high contribution of the anaerobic energy system [1]. Previous findings indicate preferential use of anaerobic or lactic acid system in taekwondo including martial art competitions [2-4]. Conventional resistance training is a well-established technique of improving anaerobic ability [5]. High-intensity resistance exercise (RE) has a positive effect on anabolic hormones such as human growth hormone (HGH) and testosterone, resulting in an adaptive response that increases muscle strength, power, hypertrophy and endurance [6]. Furthermore, evidence suggests that resistance training is a powerful stimulus for acute increase in circulating hormone levels (e.g., testosterone, HGH, and cortisol) [7-9].

It has been proposed that resistance training should be designed and conducted in line with the intended expected-outcome of the training because the resulting physical abilities can be affected by the methods of training [10, 11]. Moreover, training variables such as intensity, rest period, and repetition can differently affect the magnitudes of acute hormonal responses [7, 12, 13]. Typically, effective exercise and training is determined by the degree of training load and the ability of the muscle to withstand the load [14-17]. Thus, it can be postulated that the expected-outcome specific optimal type of training will have a greater degree of positive hormonal responses, and muscle energetics to achieve the goals of the training. Several previous studies have suggested that exercise can alter anabolic and catabolic hormones simultaneously [18-20]. For example, exercise can stimulate insulin like growth factor 1 (IGF-I) and testosterone which are anabolic hormones, and increases cortisol levels which is a catabolic hormone [21].

Traditionally, the technical training for taekwondo includes exercises such as running and jumping rope [2]. Resistance training (or RE) can be thought to play an important role in improving taekwondo performance by increasing anaerobic performance while there is some evidence that taekwondo fighting simulation (TFS) can alter hormonal responses, specifically catabolic hormones in elite taekwondo athletes [3, 5]. However, not much is known about the hormonal responses of RE versus TS in elite taekwondo athletes. This knowledge can contribute for taekwondo performance enhancement in that it can be utilized to adjust training load and frequency, and recovery.

The aim of this study was the knowledge about hormonal such as insulin-like growth factor 1 (IGF-1), testosterone and cortisol responses between taekwondo simulation and traditional resistance exercise in elite taekwondo athletes.

MATERIAL AND METHODS

Participants

Eight Korea Armed Forces Athletic Corps taekwondo athletes volunteered to participate in this study: age 24.9 ±1.3 years; sport career 11.5 ±1.8 years; height 181.6 ±4.8 cm; body mass 75.2 ±12 kg; BMI 22.7 ±2.8 kg/m^2. Only those participants who cleared the medical screening by their physicians and were declared fit to carry out resistance exercises and competition simulations were selected. Additionally, exclusion criteria consisted of any musculoskeletal injuries or operations of the lower limbs within the past year. Informed consent forms were obtained from the participants before testing.

This study was approved by the Institutional Review Board at Korea Institute of Sport Science, Seoul, South Korea.

Experimental protocol

This research employed a randomized crossover design in which participants completed two protocols. The study did not employ a true random sample of participants, as the participants were randomly assigned to either a traditional resistance exercise (RE) protocol or a taekwondo fighting simulation (TS) protocol, during three separate visits by a period of 7 days. First visited, each participant's 1 repetition-maximum (1-RM) of squat, hip-abduction, and leg-extension were measured and given their informed consents. Respective 1-RM was used to calculate 8-RMs respectively for each participant. Second visited and third visited subjects in the two exercise protocols (TS and RE) performed.

The subjects completed a moderate-intensity 5-minute warm-up with a stationary bike. Immediately after warm-up, they performed 2 sets of squats (8-RMs) followed by hip-abduction and leg-extension exercises. A rest interval of 90 seconds was provided in between the two sets. Participants were instructed on how to safely perform each resistance. The TFS consisted of using the same methods as a real taekwondo match which included: 1) match coaching advice, 2) following the Olympic Games rules and 3) consisted of 3 rounds of taekwondo of 2 minutes each. All the testing was done in our research laboratory at the Korea Institute of Sports Science. All participants had 8 hours of fasting and 7 hours of sleeping time prior to their visits.

Blood collection and hormone analyses

Blood sampling was performed by a qualified medical laboratory technologist. The right upper arm vein was squeezed with a tourniquet in a sitting position, the needle was inserted in the vein after cleaning the site and finally blood was collected in tubes. After 30 minutes of blood collection, blood cells and plasma were separated through a centrifuge (HF 300, Hanil scientific Inc., Korea) to analyze the hormones (testosterone, cortisol and IGF-1). Enzyme immunoassay was performed using an enzyme-linked immunosorbant assay (ELISA) kit (R&D systems Inc., Minneapolis, MN 55413, USA), and the color reaction was measured at an absorbance of 450 nm by ELISA. The intra-assay coefficient of variation of IGF-1 was 1.44 %, cortisol was 10.18 % and testosterone was 6.28 %.

Statistical analyses

The 2 (group; TFS vs. RE) by 3 stages (pre-, IP-, and post-15 minutes post exercise) two-way within-subject factor ANOVA was used to examine whether exercise type and time influenced hormonal responses. Results for each variable are expressed as mean and standard deviation (±). Bonferroni was used for post-hoc analysis. Normality of dependent variables were determined by Shapiro-Wilk tests. We performed our statistical analysis by SPSS 23.0 statistical package (IBM Analytics, Chicago, IL). All significance levels were set at $p \le 0.05$.

RESULTS

Changes in IGF-1 concentration

Results from two-way within-factor ANOVA showed that main effect of stage of experiment ($F(2,14) = 6.40$, $p = 0.01$, $\eta 2 = 0.48$) and interaction effect ($F(2,14) = 3.72$, $p = 0.05$, $\eta 2 = 0.35$) were statistically significant while main effect of type of exercise ($F(1,7) = 0.01$, $p = 0.92$, $\eta 2 = 0.00$) was not significant (Table 1). Post-hoc analysis using Bonferroni indicated that IGF-1 concentration was greater at IP than Pre (Mdiff = 12.17, SE = 3.2, $p = 0.02$) and at IP than Post-15 (Mdiff = 10.6, SE = 1.95, $p = 0.003$) after TFS (Table 2). Any significant change was not detected after RE (Figure 1).

Changes in cortisol concentration

Results from two-way within-factor ANOVA showed that main effect of stage of experiment ($F(2,14) = 10.53$, $p = 0.002$, $\eta 2 = 0.60$) and

Performance – *noun* the level at which a player or athlete is carrying out their activity, either in relation to others or in relation to personal goals or standards [35].

Technique– *noun* a way of performing an action [35].

Recovery – noun 1. in swimming or rowing, the bringing forward of the arm to make another stroke **2.** the process of returning to health after being ill or injured [35].

Warm-up – *noun* an exercise or a period spent exercising before a contest or event [35].

Match – *noun* **1.** a contest between opponents, especially a sporting contest **2.** somebody or something capable of competing equally with another person or thing [35].

Training load – "A simple mathematical model of training load can be defined as the product of qualitative and quantitative factor. This reasoning may became unclear whenever the quantitative factor is called 'workload volume' or 'training volume' interchangeably with 'volume of physical activity'. Various units have been adopted as measures i.e. the number of repetitions, kilometres, tons, kilocalories, etc. as well as various units of time (seconds, minutes, hours) (...) As in the real world nothing happens beyond the time, the basic procedure of improvement of workload measurement should logically start with separation of the time factor from the set of phenomena so far classified together as '***workload volume***'. (...) Due to the fact that the heart rate (HR) is commonly accepted as the universal measure of workload intensity, the product of effort duration and HR seems to be the general indicator of ***training load*** defined as the amount of workload. It is useful in analyses with a high level of generality. (...) In current research and training practice the product of effort duration and HR was referred to as conventional units' or further calculations have been made to convert it into points." [38, p. 238].

Table 1. ANOVA table of IGF-1.

Source	SS	df	MS	F	p	η^2
Type of exercise	2.34	1.00	2.34	0.01	0.92	0.00
Error (type of exercise)	1564.16	7.00	223.45			
Stage of experiment	668.61	2.00	334.31	6.40	0.01*	0.48
Error (stage of experiment)	731.42	14.00	52.24			
Type · stage	148.47	2.00	74.23	3.73	0.05*	0.35
Error (type · stage)	278.40	14.00	19.89			

*$p \le 0.05$

Table 2. Measurements of each hormone concentration (unit: ng/mL) in taekwondo athletes (n = 8) during stages of the experiment under the influence of various types of exercises – variable are evaluated by mean and SD (±).

Hormone	Stage	Type of exercise			
		taekwondo fighting simulation		resistance exercise	
IGF-1	Pre	133.39	±20.96	137.74	±25.51
	IP	145.56	±20.19	141.38	±22.48
	Post-15	134.96	±21.84	136.13	±26.68
Cortisol	Pre	107.17	±10.67	128.43	±14.08
	IP	96.6	±16.95	97.3	±18.79
	Post-15	109.47	±19.74	95.25	±25.4
Testosterone	Pre	12.55	±2.73	11.22	±1.95
	IP	14.53	±3.85	12.36	±1.97
	Post-15	12.86	±3.19	11.2	±1.52

Pre pre exercise; **IP** immediate post exercise; **Post-15** fifteen minutes post exercise

interaction effect (F(2,14) = 10.53, p = 0.002, η2 = 0.60) were statistically significant while main effect of type of exercise (F(1,7) = 0.19, p = 0.67, η2 = 0.03) was not significant (Table 3). Post-hoc analysis using Bonferroni indicated that cortisol concentration was lower at IP than Pre (Mdiff = –31.14, SE = 6.46, p = 0.006) and at Post-15m than Pre (Mdiff = –33.18, SE = 8.15, p = 0.014) after RE (Table 2). Any significant change was not detected after TFS (Figure 2).

Changes in testosterone concentration

Results from two-way within-factor ANOVA showed that only main effect of stage of experiment (F(2,14) = 25.73, p<0.001, η2 = 0.79) was statistically significant while main effect of type of exercise (F(1,7) = 4.89, p = 0.06, η2 = 0.41) and interaction effect (F(2,14) = 0.95, p = 0.41, η2 = 0.12) were not significant (Table 4). Post-hoc analysis using Bonferrroni adjustment for main effect of time indicated that testosterone concentration was greater at IP than Pre (Mdiff = 1.56,

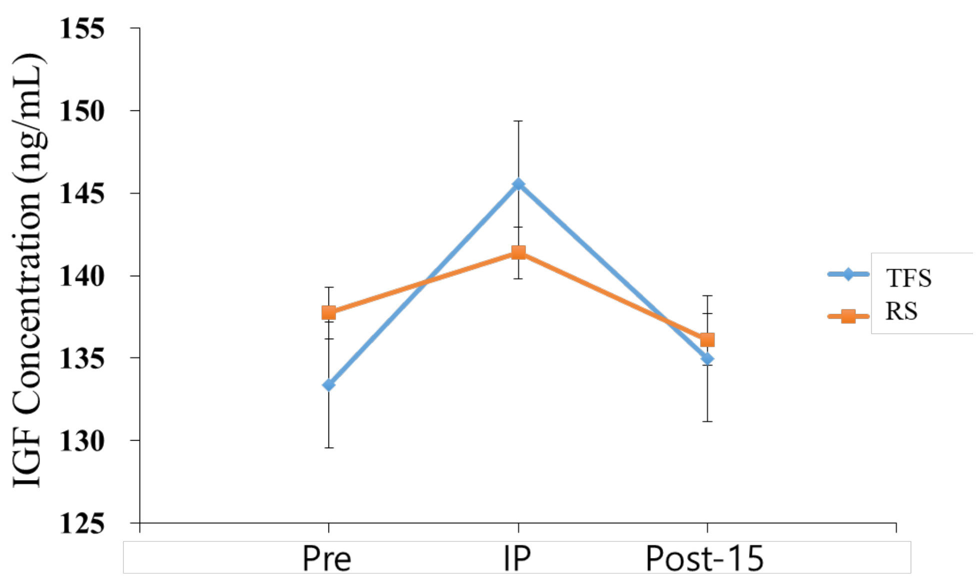

Figure 1. Changes in serum IGF-1 concentration during stages of the experiment under the influence of various types of exercises (**TFS** taekwondo fighting simulation; **RE** resistance exercise; **Pre** pre exercise; **IP** immediate post exercise; **Post-15** fifteen minutes post exercise).

Table 3. ANOVA table of cortisol.

Source	SS	df	MS	F	p	η^2
Type of exercise	79.80	1.00	79.8	0.19	0.67	0.03
Error (type of exercise)	2878.76	7.00	411.25			
Stage of experiment	3745.92	2.00	1872.96	10.53	0.002*	0.60
Error (stage of experiment)	2489.56	14.00	177.83			
Type · stage	2540.40	2.00	1270.2	10.53	0.002*	0.60
Error (type · stage)	1689.22	14.00	120.66			

*p≤ 0.05

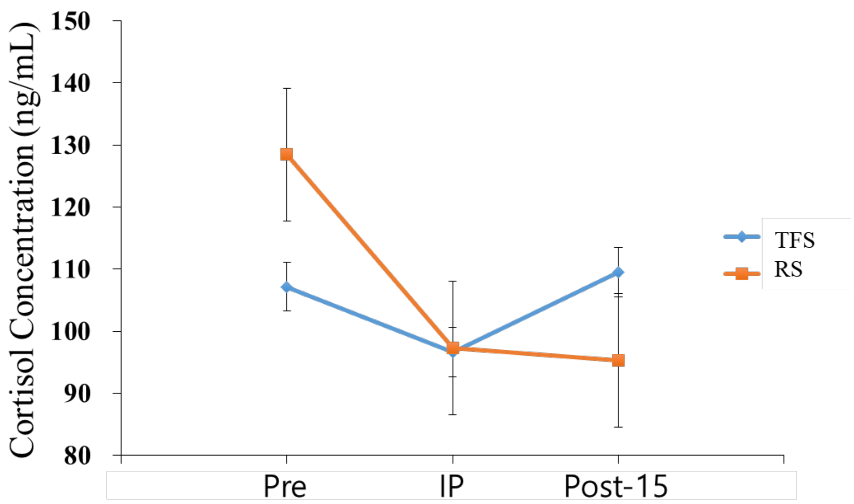

Figure 2. Changes in serum cortisol concentration during stages of the experiment under the influence of various types of exercises (**TFS** taekwondo fighting simulation; **RE** resistance exercise; **Pre** pre exercise; **IP** immediate post exercise; **Post-15** fifteen minutes post exercise).

SE = 0.29, p = 0.003) and lower at Post-15 than IP (Mdiff = –1.42, SE = 0.25, p = 0.002) in the both type of exercise (Table 2 and Figure 3).

DISCUSSION

The main findings of this study were: 1) IGF-1 levels increased immediately at IP and decreased at post-15 minutes after the TFS; 2) cortisol level under influence the RE decreased continuously immediately at IP and at post-15 minutes; 3) testosterone levels increased at IP and decreased at post-15 minutes after both types of exercises.

The lack of acute hormonal response due to RE may be in part, due to the time to reach the peak value after the release of stimulated growth hormone [22]. Lack of IGF-1 response post RE is not surprising as it has been reported before [23-25]. Typically, growth hormone stimulates mRNA synthesis after which it may take up to 9 hours for the release of IGF-1 from the liver source to its peak value [26]. Since, IGF-1 is an anabolic hormone, it could be inferred that TFS versus IGF-1 contributed more to the anabolism of skeletal muscle than the RE in this study.

Unexpectedly, cortisol levels decreased immediately after exercise in both the types of exercises compared to pre-exercise. In case of TFS, it increased at 15 min after exercise than at pre-exercise and continued to decrease with time during the RE. Previous studies have shown that high-intensity vs low intensity exercise increased cortisol secretion to a greater degree [27]. Moreover, increased secretion of cortisol has been reported after acute resistance exercise [20]. Davies and Few [28] reported that

Table 4. ANOVA table of testosterone.

Source	SS	df	MS	F	p	η²
Type of exercise	35.57	1.00	35.57	4.89	0.06	0.41
Error (type of exercise)	50.88	7.00	7.27			
Stage of experiment	23.80	2.00	11.90	25.73	0.00*	0.79
Error (stage of experiment)	6.47	14.00	0.46			
Type · stage	1.42	2.00	0.71	0.95	0.41	0.12
Error (type · stage)	10.40	14.00	0.74			

*p≤0.05

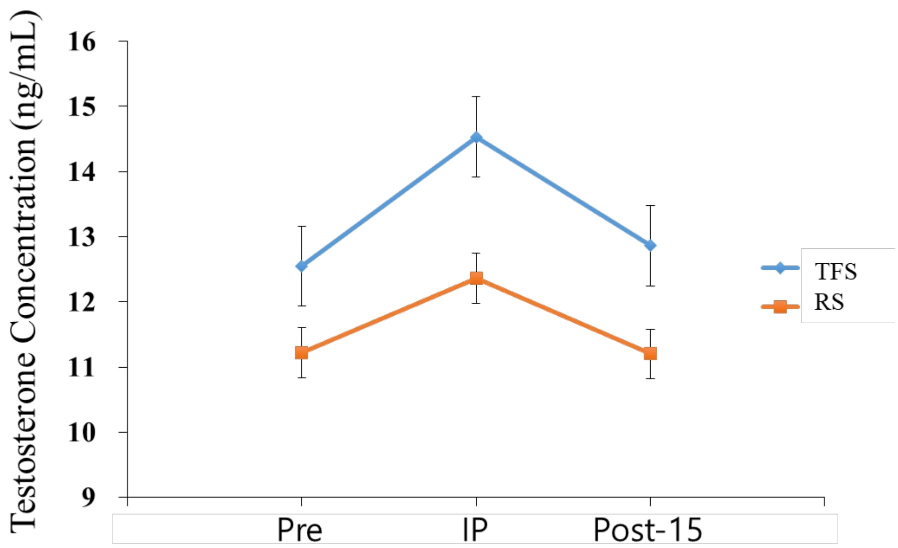

Figure 3. Changes in serum testosterone concentration during stages of the experiment under the influence of various types of exercises (**TFS** taekwondo fighting simulation; **RE** resistance exercise; **Pre** pre exercise; **IP** immediate post exercise; **Post-15** fifteen minutes post exercise).

exercise with an intensity of 60% or more of VO2max increases cortisol concentration and exercise at a lower intensity reduces it.

Results of our study are in contrast to previous studies. Because stress hormones such as cortisol differ in the amount of secretion depending on the level of fitness, it is conceivable that an athlete may have different results from the same level of exercise intensity [28]. In addition, resistance exercise in our study showed a continuous decrease in cortisol. On the other hand, in view of the relationship with other hormonal responses (greater IGF-1 and testosterone responses during the TFS), it may be interpreted that resistance exercise was not enough to cause micro damage of muscles. Although there was a significant difference in the cortisol levels at rest between the two types of exercises, nevertheless, both types showed a decrease in cortisol levels immediately after exercise. Thus, it could be inferred that various factors could influence hormone secretion, such as exercise intensity, number of sets, and number of repetitions.

It is well-established that RE elevates testosterone concentration [13, 23, 25, 29-32]. Increased testosterone after RE plays an important role in adaptation and muscle growth of skeletal muscle. Previous studies related to various exercise training methods have shown that changes in resting concentration related to the acute response of growth hormone or the ratio of testosterone, cortisol, and testosterone / cortisol are closely related to changes in muscle size and muscle strength [11, 33, 34].

The results of our study showed that both types of exercises increased testosterone hormone levels immediately after exercise compared to pre exercise and decreased at 15 minutes after exercise. There was no interaction effect between the types of exercises and stages of experiment, and only the main effect stages of experiment was statistically significant. Thus, it may be interpreted that TFS and RE affected anabolic hormonal response to the same degree in examined of taekwondo athletes population.

CONCLUSIONS

Our study showed that both RE and TFS can affect hormonal response to the same degree in elite taekwondo athletes. Future studies are required to compare the hormonal responses by setting the same energy consumption of TFS and RE. It is also important to study the differences in hormone changes with respect to physical abilities of individuals. Finally, taking into account the relationship of IGF-1 to growth hormone release, an attempt is also needed to confirm the chronic response of the hormone.

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