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REVIEW

The Effect of Resistance Exercises on Testosterone

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Abstract

Metabolism rearranges metabolic activities in order to adapt to internal or external stresses to which it is exposed. Since training creates a stress in the body, it triggers the adaptation process of the metabolism. However, activities such as endurance or strength training initiate different adaptation processes on the metabolism. The aim of our study is to examine the acute and chronic effects of resistance exercises on testosterone. For this purpose, a search with the English language limitation was made in Google Scholar, PubMed and EBSCO databases from the studies conducted before September 2020. Only studies in English language were included and articles only were cited in our study. When the studies were examined, it was emphasized that in order for resistance exercises to increase the testosterone hormone acutely or chronically, the training must be of sufficient volume and high intensity. However, it was seen that metabolism gives high testosterone responses especially to hypertrophy type resistance exercises. In addition, increases in testosterone vary depending on whether the training program is aimed at large muscle groups, the use of free weights or functional exercises, the priority of training large muscle groups in training programs, low body fat percentage, and the average young age of the research group.

Keyword: Resistance exercise, testosterone, hormone.

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INTRODUCTION

Resistance exercise is a training method used in both athletes and the non-athletic population to achieve muscle hypertrophy and improve performance (power, strength, endurance) (Crewther et al., 2016). Resistance exercise, also called strength and weight training, involves the voluntary contraction of the muscles against an external resistance. This resistance might also be the one created by body weight as it is in jumping, training with free weights, using exercise machines etc. (Riachy et al., 2020).

Strength development and muscle hypertrophy depend on the type and intensity of the load as well as the volume of strength training the athlete performs (Ahtiainen et al., 2003). The volume of training is the sum of the total number of repetitions performed multiplied by the resistance used. The volume of training is influenced by the number of sets, repetitions and exercises performed, as well as the training frequency (intensity) (Riberio et al., 2016). Exercise volume can be increased or decreased by changing the number of exercises per session, the number of repetitions per set, or the number of sets per exercise (Ratemes et al., 2002).

Resistance exercises are stated to increase hormonal concentrations in circulation. (Adebero et al., 2020). Hormone regulation becomes more important for muscle hypertrophy and strength development, especially in athletes with a long and intense training history (Ahtiainen et al., 2003).

One of the hormones that vary depending on resistance exercises is testosterone (Fry and Lohnes, 2010; Rahimi et al., 2010). Testosterone is an anabolic and androgenic hormone produced by the testicles in men (O'Leary and Hackney, 2014). Anabolic hormones stimulate muscle protein synthesis (Bush et al., 2003). Therefore, resistance exercises increase muscle strength and hypertrophy (Hansen et al., 2001). However, the increase in testosterone concentration of resistance exercises are affected by the number of sets in a training (Gotshalk et al., 1997), the number of repetitions of the exercises (Bottaro et al., 2009), the training volume (Spiering et al., 2008), and the differences in the rest periods between the sets (Bottora et al., 2009).

The aim of our study is to examine the studies in the literature on the effects of resistance exercises on testosterone, and to collect the effects of different training protocols on testosterone in a single source. For this purpose, first of all, testosterone physiology will be explained. The next part includes the review of the previous studies. Finally, the testosterone responses of different resistance exercise programs will be discussed.

The Physiology of Testosterone

Testosterone (17 β-hydroxy-4-androsten-3-one) is a 0.288 kD C_{19} steroid hormone produced from cholesterol through a series of transformations catalyzed by specific enzymes. Each step of the T synthesis is shown in Figure 1. This process takes approximately 20-30 minutes from start to end product (Vingren et al., 2010). While T is produced in Leydig interstitial cells (testicles) in men, it is produced in the ovaries in women. In addition, a small amount of T is produced in the adrenal glands (Casanova et al., 2020). T is an anabolic hormone that causes the activation of many important anabolic processes including increases in transcription, translation, signaling enzymes, and structural proteins. Although the physiological effects of exercise on T were not adequately determined, transient elevations in

T may be important for strength development, hypertrophy (Hooper et al., 2017; Mangine et al., 2018), and the psychological preparation of an athlete for a competition (Casto and Edwards, 2016).

Acute Testosterone Response to Resistance Exercises

Human metabolism gives different testosterone responses for different training variables. In many studies, it was observed that testosterone increased acutely. Baker et al. (2006) examined the effects of resistance training on 24 young, middle-aged and old men who were physically inactive. The resistance exercise protocol, consisting of 6 exercises that work the legs, chest, back and shoulder muscles, was applied on 3 sets and it was found that testosterone increased acutely in the blood samples taken. It was observed that testosterone increased not only with resistance exercises that work the whole body, but also with resistance exercises that work one area. In a study, 5 sets of 10 repetitions of leg press exercises were applied and it was concluded that testosterone increased acutely (Ahtianien et al., 2003). There are other studies in the literature that used only one exercise for the leg muscles. In the study conducted by Ahtianien et al. (2004), it was observed that testosterone increased as a result of the applied squat exercise protocol. In another study, it was observed that testosterone increased as a result of the squat protocol applied to the research group (Fry and Lohnes, 2010). Similarly, positive testosterone responses were obtained in protocols that were applied to the leg muscles in which more than one exercise was used. Ahtianien et al. (2011a) applied a training on 8 adult strong and trained males which included 5x 10 RM leg press (leg push), 2 minutes rest, 4x 10 RM squats (squat) training and, as a result, it was found that testosterone increased acutely following the training session. In addition, studies were carried out with similar protocols for upper body exercises as well. In the study of Charro et al. (2010) applied on 10 experienced men; bench press, pec-deck and decline bench press exercises were used. As a result, it was found that testosterone increased acutely.

When the literature was examined, it was seen that different types of training cause different testosterone responses. In a study, strength (8 sets of 6 reps, maximum 45% 1 repetition [1RM], 3-minute rest periods, ballistic movements), hypertrophy (10 sets of 10 reps, 75% 1RM, 2-minute rest periods, controlled movements) or maximal strength (6 sets of 4 repetitions, 88% 1RM, 4-minute rest periods, explosion purposes) exercise protocols were applied. It was found that testosterone increased acutely in blood samples taken after exercises. However, the study emphasized that the testosterone responses given by the hypertrophy training protocol were greater when compared to other protocols (Crewther et al., 2008). In another study comparing protocols of strongman training, hypertrophy training and the combination of these two trainings; testosterone test results of all groups were found to be significant in the blood samples taken before and after the training. Hypertrophy training protocol gave a greater testosterone response compared to other protocols (Ghigiarelli et al., 2013). In another study comparing the effects of hypertrophy and maximal strength training protocols, while testosterone increased in both protocols, hypertophy training resulted in higher testosterone responses than maximal strength training (Vilanueva et al., 2012). In their study, McCaulley et al. (2009) concluded that hypertrophy training results in more testosterone responses compared to power and strength training.

Apart from the widely used resistance exercise techniques, the effects of functional exercises on testosterone were also examined. In the study conducted by Beaven et al. (2011), from the blood samples taken right after the squat exercise together with box squats or jump squats exercises, testosterone was found to increase acutely. In another study, the effects of standard resistance exercise training, strongman training and combat sports specific strength training were compared. It was found that the test results of groups that did strongman and combat type resistance exercises had higher values compared to the other groups (Gaviglio et al., 2015).

The physiological effects of different exercises that train the same area may vary. Shaner et al. (2014) examined the effects of 6 sets of 10 repetitions of squats and leg press exercises in their study in 2014. As a result, it was found that testosterone increased acutely in both groups. However, squat exercise was found to respond more to testosterone compared to leg press.

Although the applied training program is the same, the order of the exercises used also causes different testosterone responses. In a study, the effects of two training protocols were examined. One of these protocols included a training starting from small muscle groups (SMG) to large muscle groups (LMG), and the other was from LMG to SMG. As a result, it was determined that testosterone increased acutely in both groups. In addition, the LMG-SMG protocol resulted in a higher increase in testosterone level compared to the SMG-LMG protocol. (Sheikholeslami-Vatani et al., 2016).

Rest periods used between sets are effective on testosterone. In their study in 2010, Rahimi et al. (2010) examined the effects of the same resistance exercise program with the resting times of 60 seconds, 90 seconds and 120 seconds between sets. As a result, all three training protocols were found to raise testosterone acutely. In the study, it was stated that testosterone responses decreased from a 120 seconds rest period to a 60 seconds rest period.

Different training volumes affect the level of testosterone released. Spiering et al. (2009) examined the effects of knee extension and knee extension + upper body resistance exercises in their study in 2009 on 6 men aged 26 ± 4 years, with heights of 176 ± 5 cm and body weight of 75.8 ± 11.4 kg. As a result, it was found that knee extension exercise alone did not cause a significant change on testosterone, but knee extension + upper body resistance exercises increased testosterone. In addition, testosterone responses of similar volume training programs are similar. In their study conducted in 2009, Uchida et al. examined the effects of 5 different bench training protocols with set/weight (50-75-90-100-110% of 1TM) / maximum number of repetitions in the same training volume. As a result, it was found that all protocols increased testosterone except the protocol applied with 50% of 1 TM load. The study emphasized that the effects of similar volume trainings were the same.

Body fat ratio also affects the resistance exercise response. Rubin et al. (2015) examined the acute effects of resistance exercises in their study on 10 obese men with 36.2 ± 4.03% body fat and 10 athletic male volunteers with body fat percentage of 12.7 ± 2.9. As a result, it was found that testosterone increased acutely in both groups. However, the study emphasized that the group with low body fat percentage had higher testosterone responses. There are also other studies in the literature supporting that body fat percentage decreases testosterone response (Sheikholeslami-Vatani et al., 2016).

Chronic Testosterone Response to Resistance Exercises

When the literature is examined, it can be seen that there are different results about chronic testosterone response to resistance exercises applied for a long time. In some studies, it is emphasized that resistance exercises have no effect on testosterone chronically.

In 2001, Hansen et al. studied the effects of 9-week (2 days / week) arm protocol and arm + leg protocol resistance exercises in their study on 16 male volunteers without training history. No significant difference was found between the test results before and after the protocol.

In their study, Mitchell et al. (2013) examined the effects of a 16-week (4 days / week) resistance exercise program on 23 men aged 24 ± 3 years, with height of 177 ± 8 cm and body weight of 84.1 ± 16.9 kg. No significant difference was found between the test results before and after the protocol.

In their study in 2006, Sallinen et al. (2006) examined the effects of a 21-week (2 days / week) resistance exercise program on 51 elderly women between the ages of 49-74. As a result, although the testosterone values of the research group increased in the first half of the study, no significant difference was found in the measurements at the end of the study.

In the study conducted by Ahtianien et al. (2003) on 8 strength-power athletes and 8 active men in 2003, the effects of a 21-week (2 days / week) resistance exercise program were examined. No significant difference was found between the test results before and after the protocol.

In the research conducted by Ahtianien et al. (2005) on 8 strength-power athletes and 8 active men in 2005, the effects of the 6-month resistance exercise program were examined. No significant difference was found between the test results before and after the protocol.

In 2016, Riberio et al. (2016) examined the effects of 31-week traditional resistance training and pyramidal resistance training in their study on 25 women aged 67.6 ± 5.1 years, having 65.9 ± 11.1 kg body weight and 154.7 ± 5.8 cm height. No significant difference was found between the test results before and after the protocol.

In a study conducted by Ahtianien et al. (2015) on 5 young adult men aged 28 ± 3 years and 8 elderly men aged 70 ± 2 years in 2015, the effects of a 12-month (2 days / week) resistance exercise program were examined. No significant difference was found between the test results before and after the protocol.

In some studies, it was concluded that resistance exercises chronically increase testosterone.

Mangine et al. (2018) examined the effects of 5-week (1 day / week) high-intensity functional resistance exercises in their study on 5 male and 5 female volunteers in 2018. There was a significant difference between the test results before and after the protocol.

The effects of the 8-week (3 days / week) resistance exercise program were examined by Arazi et al. (2012) on 8 middle-aged men aged 49.7 ± 2.1 years and 10 young men aged 21.2 ± 2.2 years. There was a significant difference between the test results before and after the protocol. It was also noted that middle-aged men react differently to resistance exercises compared to young men.

Crewther et al. (2016) conducted an 8-week (3 days / week) full body and split body resistance exercise program on 24 male volunteers aged 29.8 ± 6.8 years, with height of 179.5 ±

7.9 cm and body weight of 92.9 ± 12.2 kg. There was a significant difference between the test results before and after the protocol. In addition, the split body protocol increased testosterone more compared to the full body protocol.

Schwanbeck et al. (2020) conducted a study on 20 male and 26 female volunteers between the ages of 18-30, examining the effects of resistance exercise programs applied with free weights (2 days training/1 day rest) and exercise machines for 8 weeks. There was a significant difference between the test results before and after the protocol. In addition, the group that trained with free weights had higher testosterone responses.

In the study of Mangine et al. (2016) conducted on 26 men with resistance exercise experience, the effects of high volume protocol and high intensity protocol resistance exercises for a 9-week period (4 days / week) were examined. There was a significant difference between the test results before and after the protocol. Furthermore, increased testosterone levels were associated with hypertrophy training. Rønnestad et al. (2011) examined the effects of an 11-week (2 days / week) resistance exercise program in their study on 9 male volunteers. There was a significant difference between the test results before and after the protocol. Roberts et al. (2013) examined the effects of 12-week (3 days / week) full body resistance exercises on 36 obese adults aged between18-35. There was a significant difference between the test results before and after the protocol. Moradi (2015)'s study on 21 obese men was examined the effects of a 20-week (3 days / week) resistance exercise program. There was a significant difference between the test results before and after the protocol.

CONCLUSION

The release of some hormones increases in response to the stress caused by resistance exercises on metabolism. One of these hormones is testosterone. Testosterone is a hormone that is directly associated with sports performance, especially because of its association with muscle building and strength. In our study, acute and chronic testosterone responses of resistance exercises were examined. When the studies were examined, it was emphasized that the training applied to increase the testosterone acutely should be of sufficient volume and the exercise should be at a high intensity. Besides, it was seen that metabolism gives high testosterone responses especially to hypertrophy type resistance exercises. Furthermore, it was determined that acute increases in testosterone vary depending on whether the training program is aimed at large muscle groups, the use of free weights or functional exercises, the priority of large muscle groups in training programs, and low body fat percentage.

Different results emerged in studies about chronic testosterone responses of resistance exercises. In some of the studies, no changes in testosterone levels were observed chronically. Researchers state that this is due to the training program that is used to train small muscle groups, the nutrition program, the adaptation of metabolism to the training program and the high average age of the research group. There are also studies stating that resistance exercises chronically increase testosterone release. The researchers argue that the reasons for this increase in testosterone levels are due to the decreased body fat percentage, increased muscle mass, the volume of training used, the low average age of the research group and the use of free weights.

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