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Research Article

Effects of resistance exercise type on cortisol and androgen cross talk in resistance-trained women

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Abstract

The current study aimed to compare the effect of hypertrophy-, strength-, and power-type resistance exercise on resistance-trained women considering cortisol and androgen cross talk. After one-repetition maximum (1-RM) estimation, ten resistance-trained women (age: 26.30 ± 4.95 years; body mass index: 22.07 ± 2.02 kg/m2; body fat: 24.64 ± 4.98%) conducted hypertrophy- (70% of 1-RM), strength- (90% of 1-RM), and power-type (45% of 1-RM) resistance exercise for three consecutive weeks. The movements included lever leg extension, reverse-grip lat pull-down, horizontal leg press, standing biceps cable curl, lying leg curl, machines bench press, standing cable triceps extension, and seated calf raises. Fasting blood was taken before and immediately after each trial. Statistical analyses were performed at a significance level of P <0.05. All resistance exercise types caused a significant decrease in serum cortisol levels. Strength- and power-type resistance exercises reduced the serum testosterone level significantly. Hypertrophy- and power-types significantly increased the testosterone to cortisol ratio. It can be concluded that Hypertrophy-, strength-, and power-type resistance exercises can improve anabolic responses in resistance-trained women.

Key Words: Resistance exercise, Testosterone, Cortisol, Resistance-trained women

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Introduction

Acute hormonal responses to chronic changes in resting hormonal levels are vital for tissue development. It is because hypertrophy and muscle strength are not shown to affect resting hormonal levels. Resistance activity or exercise increases local endurance, hypertrophy, and muscle strength through acute physiological responses and chronic adaptations (Kraemer & Ratamess, 2005). A highly critical physiological change due to resistance activities concerns hormonal levels. The two hormones described as anabolic and catabolic in sports fields are testosterone and cortisol, respectively (Luccia et al, 2018). The testosterone to cortisol (T/C) ratio is used as an indicator of exercise pressure, where a change in this indicator implies several responses to exercise, such as hypertrophy and increased strength (Bartolomei et al, 2017).

Glucocorticoids are released from the adrenal cortex in response to exercise pressure. Among glucocorticoids, cortisol accounts for 95% of glucocorticoid activity. Cortisol has catabolic effects that exert the greatest impact on skeletal muscle type II fibers (Kraemer & Ratamess, 2005). Approximately, 10% of cortisol in the bloodstream is free, while 15% is albumin-bound cortisol, and the remaining 75% is bound to corticosteroid-binding globulin. In peripheral tissues, cortisol stimulates lipolysis in adipose cells, causing higher rates of muscle breakdown and lower rates of protein synthesis in muscle cells. The outcome is the increased release of lipids and amino acids into the bloodstream (Vingren et al, 2010). Therefore, because of its important role in tissue re-modeling, frequent research has assessed acute changes in cortisol upon resistance activity (Sheikholeslami-Vatani et al, 2016). The gonadotropin-releasing hormone stimulates the secretion of lutein after exercise, whereby lutein increases testosterone secretion by stimulating the ovarian monocytes.

Testosterone is a powerful anabolic hormone that increases muscle protein synthesis and intracellular amino acid uptake, thereby improving pure protein balance. In the skeletal muscle, testosterone stimulates protein synthesis (anabolic) and inhibits protein breakdown (anti-catabolic effect), with these effects indicating the promotion of muscle hypertrophy (Kraemer & Ratamess, 2005). The biological effects of testosterone are mediated by binding to the adrenergic receptor so that it transcribes the expression of specific genes by transferring the receptor into the nucleus (Vingren et al,

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2010). Research findings confirm the anabolic effects of testosterone on skeletal muscle. In this regard, increased muscle mass by testosterone is shown to be associated with an increase in the number of muscle satellite and nuclear cells (Sinha-Hikim et al, 2003). In addition, cortisol enhances myostatin expression through the activation of the myostatin promoter. Therefore, testosterone and cortisol concentrations and the ratio held between them indicate the process of anabolism or catabolism in the body (Vingren et al, 2010).

The major androgen in males is testosterone. The T/C ratio is used as an indicator of exercise pressure, where a higher ratio value suggests hypertrophy and increased strength in response to exercise (Luccia et al, 2018). Few studies have examined testosterone responses to resistance activity in women. Research has not observed significant changes in testosterone levels after exercise in women. One study has reported no change in total testosterone after 5 sets of 10 repetitions of sit-ups, chest press, and leg press using below maximum, maximum, and explosive workloads (Linnamo et al, 2005). Moreover, it has been shown that changing load or changing rest periods does not change the serum testosterone concentration relative to baseline in women (Kraemer et al, 1993). The preparation program for a sports competition includes hypertrophy-, strength-, and power-type activities. However, the T/C ratio following these three types of resistance activity has not been well evaluated in women. Therefore, the question that arises is whether or not the responses generated in the context of these activities are different. Also, which type of resistance exercise produces stronger responses? Therefore, this study compared the effects of hypertrophy-, strength-, and power-type resistance activities on serum levels of testosterone, cortisol, and T/C ratio in resistance training women.

Materials and Methods

Subjects

Table 1. Hypertrophy-type, strength-type, and power-type resistance protocols

Type of activity	Hypertrophy-type activity	Strength-type activity	Power-type activity
Number of sets	3	3	3
Repetitions	10-12	3-5	8-10
Number of stations	8	8	8
Rest between sets (seconds)	60-90	60-120	60-180
Rest between stations (seconds)	60-90	60-120	60-180
Performance speed	moderate	moderate	explosive

Ten healthy female resistance practitioners living in Mashhad (age: 26.30 ± 4.95 years; weight: 59.51 ± 7.78 kg; body mass index: 22.07 ± 2.02 kg/m2) participated in this quasi-experimental study. Subjects were selected by in-person visits to bodybuilding gyms and advertisements placed in gyms and associated Telegram groups. Inclusion criteria comprised performance of resistance training regularly and recreationally for more than a year; performance of at least three sessions of resistance training per week; regular menstrual periods non-addiction to alcohol, cigarettes, and other drugs; non-consumption of drugs; non-use of hormones and nutritional supplements; and absence of cardiovascular diseases, especially hypertension. The subjects completed a health survey, and the possible benefits, risks, and procedures of the study were explained to them. Subsequently, they signed written consent forms for participation.

1RM test

One week before starting the training protocol, the 1-RM of the agonist and antagonist muscles were estimated on two separate days. First, the subjects warmed up each specific muscle for 5 minutes using stationary bicycles and very light weights. After 3 minutes of rest, the 1-RM estimation process was initiated. Based on the subjects' estimates, a weight was selected that the subject could lift correctly from a minimum of one time to a maximum of 10 times. By substituting the weight value and the number of repetitions in the Brzycki 1-RM prediction equation, i.e., (1 = weight ÷ [1.027 – (0.27 × number of repetitions)], 1-RM was obtained in each movement.

Exercise training protocol

The resistance activity protocol involved three stages with one-week intervals. One week after 1-RM estimation, hypertrophy-type resistance activity was performed (70% 1-RM) and was followed by strength-type resistance activity (90% 1-RM). Lastly, resistance activity was implemented for power development (45% 1-RM). Each session began with 10 minutes of warm-up and concluded with 5 minutes of cooling. The movements were performed successively in a row and included lever leg extension, reverse-grip lat pull-down, horizontal leg press, standing biceps cable curl, lying leg curl, machines bench press, standing cable triceps extension, and seated calf raises. After each performance, the subjects resumed their daily lives. However, they were prohibited from performing any exercise, especially resistance, during the protocol run, specifically 48 hours before each performance. The number of sets, repetitions, and rest times between each set and station are presented in table 1.

Measurements

A nurse took 7 cc of fasting blood (8 hours) (Bartolomei et al, 2017, Levers et al, 2015) from the brachial vein of the subjects before and immediately after they completed the three resistance activities at Anoush gym (Mashhad, Iran). Blood samples were collected and tra-

-nsferred immediately to Arad Medical Laboratory (Mashhad, Iran) for serum isolation. The samples were centrifuged at a speed of 1500 rpm at 10 °C for 10 minutes (Universal model, Behdad Co., Iran). The resulting sera were stored at -80 °C (GFL laboratory freezer, Germany). The testosterone was assessed biochemically using 96-well commercial kits (Zellbio, Germany; catalog number: 9648H-10041-ZB). It was assessed with a sensitivity of 0.02 and a detection range of 0.08 to 16.7 ng/ml using the sandwich ELISA method based on the antigen-antibody reaction.

Biochemical evaluation of cortisol was performed using 96-well commercial kits (Zellbio, Germany; catalog number: 9648H-11003-ZB). It was assessed with a sensitivity of 0.04 and a detection range of 0.5 to 60 mg/dl using the sandwich ELISA method based on the antigen-antibody reaction. Serum concentrations of these variables were read by Biotek Microplate Reader (Model 2EpocH, USA) in the biochemistry laboratory of Gonabad University of Medical Sciences.

Nutrition

One week before the program, the subjects completed the 3-day food records. Subjects received 58% of their calories from carbohydrates, 15% from protein, and 27% from fat. Studies indicate that such a normal nutritional status does not affect the circadian testosterone cycle (Ruige et al, 2011). Because a high-fat diet (more than 44%) affects testosterone levels, subjects were prevented from eating fatty foods during the period (Shariat et al, 2015). Low carb intake (30% of meals) increases the free T/C ratio by 43% in response to strenuous activity. However, adequate carbohydrate intake (60% of meals) does not affect cortisol-free testosterone levels in response to exercise (Lane et al, 2010). Therefore, glycogen loading was performed three days before RM-1 estimation and hypertrophy-, strength-, and power-type resistance activities.

In addition, they were requested not to use steroid, protein, vitamin, and mineral supplements from one week before the protocol implementation to the end of it. Combined consumption of carbohydrates and protein, as well as amino acids (Vingren et al, 2010), affect the hormonal response to testosterone (Shariat et al, 2015). Thus, the participants were requested not to take nutritional supplements in the form of carbohydrates, proteins, amino acids, or anabolic steroids (Shariat et al, 2015). Caffeine consumption one hour before resistance activity increases cortisol and testosterone levels in response to resistance activity (Beaven et al, 2008). Therefore, the subjects abstained from taking supplements during the study period and one hour before each resistance exercise (Beaven et al, 2008).

Statistical analysis

For statistical evaluation of the data, version 16 of the Statistical Software for Social Sciences (SPSS Institute, Chicago, USA) was used. The significance level was considered at $P < 0.05$. The normal distribution of data was assessed by the Shapiro-Wilk test. In this regard, the parametric Wilcoxon dependent t-test and the non-parametric Wilcoxon test were used to evaluating between-factor differences. Moreover, statistical methods of analysis of covariance and Bonferroni post hoc test were employed to assess the between-factor changes in the post-test stage. The results are displayed as mean ± standard error.

Results

Within-group evaluation showed that serum cortisol levels decreased significantly after hypertrophy- (17.29 ± 1.20 to 10.17 ± 1.27 µg/dl; P = 0.017), strength- (17.96 ± 2.51 to 10.62 ±1.22 µg/dl; P = 0.008), and power-type resistance activities (17.95 ± 2.13 to 9.67 ± 1.31 µg/dl; P = 0.001). Nonetheless, between-factor evaluation showed no significant difference between the three types of resistance activities (P = 0.795) (Figure 1A).

Serum testosterone levels reduced significantly after strength-type (1.28 ± 0.23 to 1.03 ± 0.19 ng/ml; P = 0.001) and power-type strength activities (1.27 ± 0.24 to 1.04 ± 0.23 ng/ml; P = 0.012). However, serum testosterone levels increased following hypertrophy-type resistance activity (1.03 ± 0.15 to 1.07 ± 0.19 ng/ml; P = 0.616). The results of between-factor evaluation showed that serum testosterone levels following strength-type (P = 0.014) and power-type resistance activity (P = 0.006) were significantly lower than after hypertrophy-type resistance activity. However, no significant difference was observed between serum testosterone levels following strength-type and power-type resistance activities (P = 0.999) (Figure 1B).

T/C ratio increased significantly following hypertrophy-type (0.061 ± 0.010 to 0.112 ± 0.022; P = 0.010) and power-type resistance activities (0.076 ± 0.013 to 0.121 ± 0.031; P = 0.012). T/C ratio showed a 35.80% increase after strength-type resistance activity (0.081 ± 0.016 and 0.110 ± 0.025). Between-factor evaluation showed no significant difference between the responses of the three types of resistance activities in terms of T/C ratio (P = 0.436) (Figure 1C).

Discussion

T/C ratio is used to assess whether exercise causes catabolic or anabolic conditions in the body (Luccia et al, 2018). In this regard, research indicates that the implementation of resistance from large to small muscles results in more anabolic hormonal responses than the other way round (Sheikholeslami-Vatani et al, 2016). Besides, high-intensity resistance activity causes higher catabolic events than high-volume resistance activity in trained men (Bartolomei et al, 2017). The results of the present study showed that all three types of resistance activities, namely, hypertrophy-type, strength-type, and power-type, increased the T/C ratio by 83.63%, 35.80%, and 59.21%

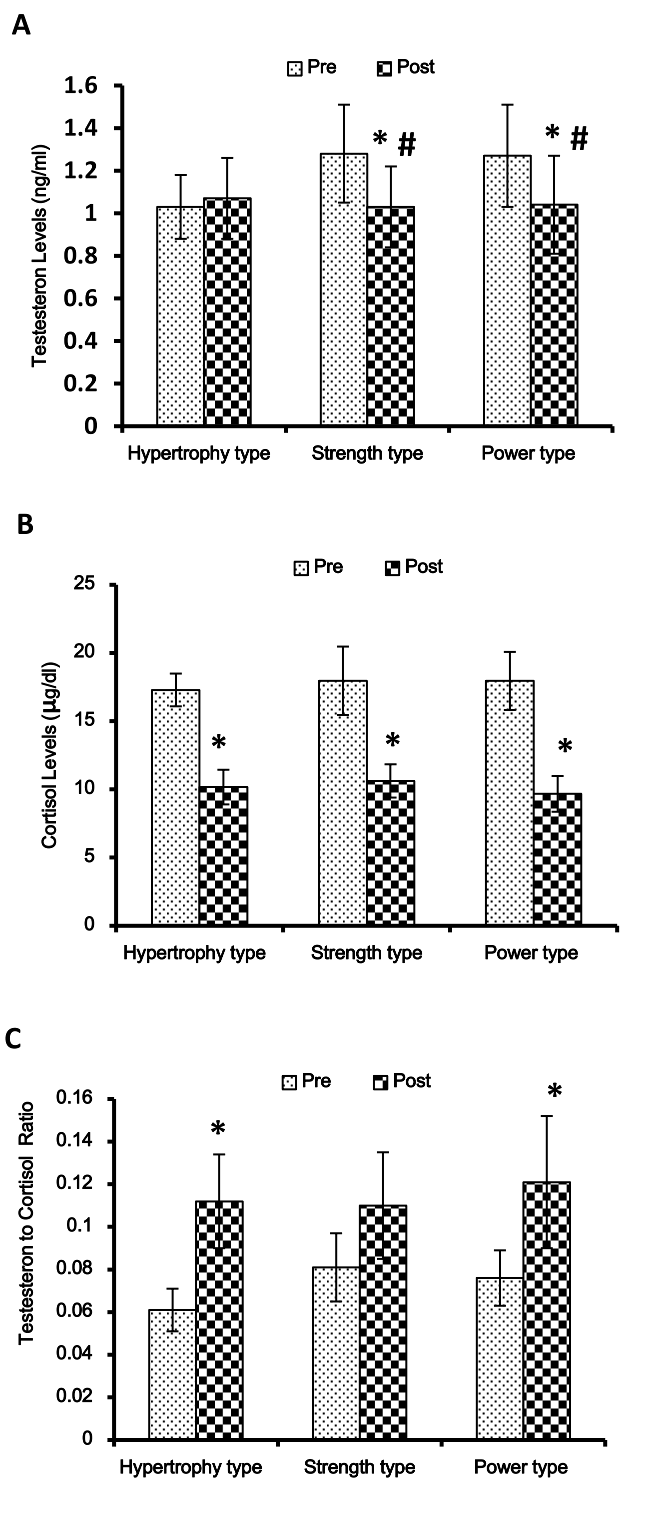

Figure 1. Effects of hypertrophy-, strength- and power-type resistance exercises on serum testosterone (A), cortisol (B), and testosterone to cortisol ratio (C). The asterisk (*) indicates a significant difference from the pre-treatment value. The hash sign (#) indicates a significant difference from hypertrophy-type resistance exercise at post-stage.

, respectively. Nevertheless, the difference was not significant between the three types of resistance activity, suggesting that they all improve anabolic conditions in resistance-trained women. Although hypertrophy-, strength-, and power-type resistance activities were performed at rest intervals of 90, 120, and 180 seconds between sets, respectively, and an increase in T/C ratio was observed, resistance performance at rest intervals of less than 1 minute reduces the T/C ratio (Henselmans et al, 2014).

Longer rest periods (120 seconds) between resistance sets increase the T/C ratio more than short rest durations (60 seconds) in resistance-trained men (Rahimi et al, 2011). Nevertheless, strength- and power-type resistance activities performed at 120- and 180-second rest intervals between sets did not cause a significant difference in the T/C ratio compared to hypertrophy-type resistance activities performed at 90-second intervals between sets. The current study fundings are consistent with reports of an increase in T/C ratio following continuous and intermittent treadmill running in inactive men (Ahmadi et al, 2018; Velasco-Orjuela et al, 2018). Conversely, our results are inconsistent with studies that did not show a change in the T/C ratio following two high-intensity leg presses and hack squats (da Silva et al, 2017), medium-intensity squats (Levers et al, 2015), combined resistance and power training (Casadio et al, 2017), and squat strength resistance activity (Fry & Lohnes, 2010) in untrained subjects (da Silva et al, 2017), resistance-trained subjects (Levers et al, 2015, Fry & Lohnes, 2010), and power-trained subjects (Casadio et al, 2017). Inconsistent with our results, a significant decrease in free serum and salivary T/C ratio in resistance-trained men and women immediately after exhausting endurance (Anderson et al, 2016) and the 5000-meter race (Li et al, 2015), respectively.

In addition, it has been displayed that combined resistance and power activity (3 sets at 85% to 90% 1-RM with 2 to 3 minutes of rest between sets) significantly affect plasma testosterone and cortisol levels in men and women at two temperature conditions of hot (30 ° C) and mild (20 ° C) immediately after the performance (Casadio et al, 2017). In this regard, the present protocol was implemented in mild temperature conditions, and it does not seem that the observed changes are due to temperature effects.

Our results showed that hypertrophy-, strength-, and power-type resistance activities decreased serum cortisol levels of resistance-trained (bodybuilding) women immediately after exercise. The reduction rates were 41.17%, 40.86%, and 17.26%, respectively, with no significant difference between the three resistance exercises. The results of the present study are compatible with the findings of a study, which stated that cortisol levels reduced up to 22% immediately after the implementation of large to small muscle resistance (3 sets of 10 repetitions to the point of exhaustion) and up to 12% after the implementation of small to large muscle resistance (Sheikholeslami-Vatani et al, 2016). Changes in cortisol levels immediately after resistance training do not seem to be independent of the exercise status because decreased cortisol levels after various types of acute exercise protocols are not typically reported in inactive individuals (Sheikholeslami-Vatani et al, 2016). Nevertheless, contrary to the findings of the present study, it has been shown that one session of exhausting endurance activity on the treadmill (at the ventilation threshold of 74.7 ± 4.6%) (Anderson et al, 2016) and the mere performance of high-intensity squat resistance activity (8 sets of 3 repetitions at 90% 1-RM) (Bartolomei et al, 2017) increase cortisol levels immediately (Anderson et al, 2016) and 30 minutes after exercise (Bartolomei et al, 2017) in endurance-trained (Anderson et al, 2016) and resistance-trained men (Bartolomei et al, 2017). Therefore, cortisol changes immediately after resistance exercise do not appear to be independent of the type of exercise they have previously performed. The changes observed in cortisol levels in the present study do not appear to be due to the residual effects of the preceding bout. In fact, research has shown that an acute bout of lower-body squatting activity (10 sets of 10 repetitions with 70% 1-RM intensity and 3 minutes' recovery between sets) has no significant impact on serum cortisol levels of resistance-trained men at 60 minutes, 24 h, and 48 h after exercise (Levers et al, 2015). Therefore, serum changes in cortisol following acute exercise occur only immediately up to 30 minutes after exercise (Bartolomei et al, 2017). Furthermore, the cause of the discrepancy in the results could not be interpreted in terms of gender differences because cortisol concentrations are shown to increase after the 5000 m race in both men and women with no significant differences between the secretion rates in the two genders (Li et al, 2015).

The results of the present study showed that the hypertrophy-type resistance activity did not exert a significant effect on serum levels of total testosterone. However, the strength- and power-type resistance activities reduced 19.53% and 18.11% of serum total testosterone levels of resistance-trained women, respectively. Although testosterone increases muscle protein synthesis, reduced concentration of this hormone can shift the path of amino acids from synthesis to the process of gluconeogenesis (Ahmadi et al, 2018). Two studies have reported similar reductions in blood flow testosterone concentrations following high-volume lower-body resistance activity. In this context, it has been reported that high-intensity squatting resistance activity (20 sets with 100% 1-RM) and high-volume resistance activity (10 sets, 10 repetitions at 70% 1-RM) reduce total and free serum testosterone levels in bodybuilding men the day after exercise (Hakkinen et al, 1993). In addition, one session of high-volume, lower-body resistance exercise (6 sets of 10 to 12 repetitions at 70% 1-RM) decreases serum testosterone levels within 1 to 2 hours after exercise in resistance-trained men (Gonzalez et al, 2015). Furthermore, a slight reduction in testosterone levels has been reported 30 minutes after two types of high-volume resistance squatting exercise (8 sets of 10 repetitions at 70% 1-RM) and high-intensity resistance squatting activity (8 sets of 3 repetitions at 90% 1-RM) in resistance-trained men (with a history of resistance training of 6.3 ± 3.4 years) (Bartolomei et al, 2017). Testosterone is hydrophobic and does not dissolve in the blood easily; instead, nearly all testosterone in the bloodstream binds to binding proteins that are hydrophilic (Vingren et al, 2010). In this context, it has been reported that one bout of resistance activity (6 sets, 10 repetitions of squats with 2-minute rests between sets) increases serum levels of sex hormone-bound gonadotropin in inactive healthy women. Thus, part of the decrease in testosterone levels observed in the present study may be linked with the increase in sex hormone-bound gonadotropin (Nindl et al, 2001).

Conclusion

In addition to hypertrophy-type resistance activities, strength- and power-type resistance activities can also produce an anabolic hormonal response. It can justify the hypertrophy observed in athletes who engage in such activities on a daily basis. Therefore, if the goal is to develop the anabolic environment and promote post-exercise hypertrophy, one should consider the implementation of strength- and power-type activities. Hence, women who seek to develop body mass in gyms can use strength- and power-type resistance activities.

What is already known on this subject?

Hypertrophy-, strength-, and power-type resistance exercises can improve anabolic responses in resistance-trained women.

What this study adds?

In addition to hypertrophy-type resistance exercise, women can use strength- and power-type resistance activities to develop body mass.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in current study involving human participants were in accordance with ethical standards of the institutional research committee and with the 1975 Helsinki Declaration and its later amendments or comparable ethical standards. The study was approved by the ethical committee of Bojnord University (No. 3925).

Informed consent In addition, all participants signed a written informed consent form that was approved by the ethical committee.

Author contributions

Conceptualization: H.T.C., S.M.; Methodology: H.T.C., A.G.; Software: A.G.; Validation: H.T.C., S.M.; Formal analysis: H.T.C., A.G., S.M.; Investigation: H.T.C., A.G., S.M.; Resources: H.T.C.; Data curation: H.T.C., S.M.; Writing - original draft: H.T.C., A.G.; Writing - review & editing: H.T.C., A.G., S.M.; Visualization: H.T.C.; Supervision: A.G.; Project administration: H.T.C..; Funding acquisition: S.M., A.G.

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