Alteration of testosterone:cortisol ratio induced by resistance training in women

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ABSTRACT

The ratio between the concentration of testosterone and cortisol (T:C) is frequently used as indicative of the stress level imposed by the exercise. Alterations in the concentration of these hormones are responsible for modulating several responses induced by training, such as hypertrophy and strength gain. The objective of the present study was to investigate the influence of the resistance training protocol, also known as multiple-series (MS), on the strength gain, the muscular endurance and the relation between the concentration of catabolic hormones (cortisol) and anabolic hormones (testosterone). In order to test this hypothesis, five young women with one-year of strength training practice were submitted to the MS protocol. The blood samples were collected before and immediately after the exercise at the first day and after eight weeks of training. The 1-RM and the maximal repetition tests were also performed at the beginning and after eight weeks of strength training. No alterations on the body mass, on the IMC, on the fat mass percentage and on the maximal strength (1-RM) on bench press, squat and arm curl were observed. The number of maximal repetitions at 50% of the 1-RM was increased only for the bench press ($p < 0.05$). No alterations on the concentration of the total testosterone were observed. The cortisol plasmatic concentration, after eight weeks of training, in the rest situation, was reduced (38%; $p < 0.05$). Due to the lessening of the cortisol secretion after eight weeks of training, the T:C ratio presented elevation of 20% in the rest situation ($p < 0.05$). Although no functional alterations in the 1-RM and maximal repetitions tests were detected, the MS method induced a hormonal condition favorable to the protein metabolism.

Key words: Endocrine system. Multiple-series. Anabolism. Catabolism.

INTRODUCTION

A large number of women have recently selected the resistance training as exercise, which has become an important component of the physical fitness program. Currently, several protocols of strength training are available in order to improve different aspects of the neuromuscular system[1]; however, most of these methods are originated from the empirical observation, with no scientific corroboration[2]. The difference between these training protocols is the way the acute variables (intensity, volume and the rest period between series and the exercise order) are arranged[2,3]. Despite many controversies about the superiority of a given method comparing to other, the studies that evaluated the efficiency and adaptations caused by these long-term training systems are yet scarce[4].

The initial evidences available in literature indicate that the hormonal responses to the resistance training (for example, the increase in the growth hormone concentration or the ratio of testosterone into cortisol) are well correlated to the changes in the muscle size as well as its capacity of generating tension[5]. In other situations it is possible to observe the modulation performed by the endocrine system on the muscular adaptations. For instance, the pathologies related to the endocrine system, such as the Cushing syndrome (observed through the hyper secretion of cortisol), may lead to the suppression of the myofibrillar proteins synthesis, followed by deterioration of the different strength manifestations[6,7]. On the other hand, the increase in the concentration of hormones such as GH and testosterone stimulates the growth of the muscular mass[7,8].

Considering that the manipulation of the training variables (volume, intensity, rest period and exercise order) is capable to influence the hormonal responses that, in turn, are responsible for the enlargement of the adaptable protein synthesis[9], the objective of this study was to investigate the influence of the resistance training protocol (method of multiple series – MS) on the strength gain, muscular endurance and on the relation between the testosterone and cortisol plasmatic concentration in women.

MATERIAL AND METHODS

Subjects: Five healthy, non-smokers young women (25,3 ± 2,6 years of age), who practice resistance training with experience above 12 months were selected. According to Durand *et al.* (2003)[10], the response observed in these individuals does not represent either the response of beginners or the response of highly trained athletes, but rather of many young people who engage in this type of training. The participants were submitted to the MS protocol. The data collecting was performed at the beginning and after eight weeks of training. Women presenting history of any disturbance related to the endocrine system and/or menstrual cycle were excluded. With the objective of avoiding interference from the hormonal variation observed during the menstrual cycle, the blood collecting was performed at the beginning of the follicular phase of each woman, at the beginning and at the end of the 8th week.

The experiment was approved by the Ethics Committee of Researches involving human beings of the Biomedical Sciences Institute from the University of São Paulo (advice no. 72/00). According

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Received in 6/12/03. 2nd version received in 16/3/04. Approved in 23/3/04.

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to the specific resolution of the Health National Council (no. 196/96), all participants were fully informed about the procedures used and all agreed to participate voluntarily in the study, signing an informed consent and privacy protection form. Urine samples were collected (beginning, four weeks after, and eight weeks after) in order to verify the presence of anabolic steroids; for all participants the results were negative. This analysis was performed in the Toxicological Analysis Laboratory of the Pharmaceutical Sciences School – USP.

Determination of the maximal strength (1-RM) and the capacity of maximal repetition

After a brief elongation and warm-up exercises, the maximal strength (1-RM) was determined through three progressive attempts with three-minutes interval in the following exercises: bench press, squat and arm curl[11]. Later, the percentage value corresponding to 50% of the 1-RM value was calculated (50%-1-RM) for the performance of the maximal repetition tests. The capacity of maximal repetitions was determined through the exhaustion or the incapacity to keep the movement standard.

Description of the strength training protocol: During the eight weeks, the experimental subjects trained four times a week (Monday, Tuesday, Thursday and Friday), being Monday and Thursday the training A, in which chest, backs and shoulders were worked; and Tuesday and Friday, the training B was performed, which consisted of thigh and arm exercises. The intensity was adjusted for each day as follows: Monday and Tuesday, 100% of 10 maximal repetitions (10-RM), and Thursday and Friday, 90% of 10 maximal repetitions (90%-10-RM). The endurance training was restricted to a maximum of 20 minutes, twice a week, with intervals of at least eight hours between the strength and aerobic-endurance sessions. The MS method consisted of two exercises for each muscular grouping except for the thigh muscles, with three exercises in four series of 10 repetitions for each exercise, with 90-second interval between series. The exercises were: on **training A**: bench press, dumbell incline bench press, low pull, lat pull down, lateral raise, dumbell press, **training B**: leg press, leg extension, leg curl, standing biceps curl (ez bar), alternate standing dumbell curl, triceps push down, standing french press.

Evaluation of the body composition: The body composition was evaluated through the use of a skinfold compass (*Lange*©); the protocol used was the one previously described by Jackson and Pollock[12] for women.

Plasmatic determinations: After five hours of fasting, the blood was collected before the training session at 7:00 pm, characterizing the rest situation, and shortly after the end of the training session (8:00 pm). In order to evaluate serum testosterone and cortisol concentrations, the kits by radioimmunoassay COAT-A-COUNT®, DPC were used. The participants were instructed to follow a standard menu, with fixed timetables, 24 hours before the blood collecting[1,3]. The hormonal dosages were performed in the Metabolism Laboratory of the Biomedical Sciences Institute – USP.

Statistical analysis: For the comparison between before and after the exercise and pre and post-training, the paired Student *t*-test was used. The minimum significance level of $p < 0.05$ was established.

RESULTS

With regard to the body composition (weight, IMC and fat mass), no significant differences were observed after the intervention of the MS training in relation to the initial value (table 1). The maximum strength checked through the 1-RM test in the bench press, squat and arm curl exercises presented no increase in relation to the beginning of training (table 2). The capacity of maximal repetition was high, only for bench press, in relation to the initial value ($p < 0.05$) (table 3).

The testosterone concentration did not change in any moment. The cortisol secretion before the training session (rest) was reduced (38%) after eight weeks of training ($p < 0.05$) (table 4). Immediately after the last training session in the 8th week, the cortisol concentration was high (44%) in relation to the rest situation ($p < 0.05$) (table 4). The relationship between the testosterone plasmatic concentration and the cortisol plasmatic concentration (T:C) increased 20% before the performance of the training session, in the rest situation, after eight weeks ($p < 0.05$) (table 4). Immediately after the performance of the training session (post-exercise), after eight weeks of training, a decrease (35%) on the T:C ratio was observed ($p < 0.01$) (table 4).

TABLE 1
Evaluation of the body composition performed at the beginning and at the end of the eight-week strength training (method MS)

	Weight (kg)	IMC	Fat mass (%)
Initial	57.2 ± 3.0	21.0 ± 0.8	19.5 ± 4.1
8th week	57.5 ± 3.9	21.0 ± 1.0	18.2 ± 4.0

Values expressed as average ± standard deviation. No statistical difference between both periods was verified.

TABLE 2
Determination of the value of 1-RM (kg) performed at the beginning and at the end of the 8-week strength training (method MS)

	Bench press	Squat	Arm curl
Initial	23.4 ± 11.1	55.8 ± 12.3	17.3 ± 3.8
8th week	31.2 ± 10.2	78.8 ± 18.0	19.7 ± 3.9

Values expressed as average ± standard deviation. No statistical difference between both periods was verified.

TABLE 3
Determination of the number of maximal repetitions performed at 50% of 1-RM, performed at the beginning and at the end of the eight-week strength training (method MS)

	Bench press	Squat	Arm curl
Initial	14.0 ± 2.0	40.5 ± 12.3	25.0 ± 7.5
8th week	20.0 ± 3.5[a]	46.0 ± 13.0	28.0 ± 2.7

Values expressed as average ± standard deviation. The minimal stipulated significance level was $p < 0.05$. a – statistical difference in relation to the initial value (pre-training, $p < 0.05$)

TABLE 4
Total testosterone and cortisol plasmatic concentration checked in rest situation and at the post-exercise moment, at the beginning and at the end of the eight-week strength training (method MS)

Testosterone (ηmol.L-1)	Initial	8th week
Rest	1.03 ± 0.17	0.89 ± 0.11
Post-exercise	0.90 ± 0.22	0.81 ± 0.12
Cortisol (çmol.L-1)	**Initial**	**8th week**
Rest	219.0 ± 49.4	158.0 ± 26.8[a]
Post-exercise	201.2 ± 67.2	228.1 ± 79.7[b]
Ratio	**Initial**	**8th week**
Rest	$4.6.10^{-3}$ ± $0.4.10^{-3}$	$5.7.10^{-3}$ ± $0.5.10^{-3}$[a]
Post-exercise	$4.5.10^{-3}$ ± $0.5.10^{-3}$	$3.6.10^{-3}$ ± $0.5.10^{-3}$[ab]

Values expressed as average ± standard deviation. The minimum level of significance was established as $p < 0.05$. b-statistical difference in relation to the rest situation ($p < 0.01$).

DISCUSSION

The objective of our work was to verify the influence of the MS method on the body composition, on functional parameters (maximal strength tests (1-RM) and of maximal repetitions at 50% of the value of 1-RM) and on the testosterone and cortisol ratio (T:C) in women. This ratio (T:C) has been widely used as indicative of adaptation and/or stress index.

Our data demonstrated that there was no significant alteration in the body composition of participants (table 1). Furthermore, alterations in the performance on 1-RM tests also were not detected (for bench press, squat and arm curl exercises) (table 2), as well as on the maximal repetition tests at 50%-1-RM for the same exercises, except for the bench press exercise (table 3).

In the initial collecting, no increase on the post-exercise cortisol concentration was verified (table 4). Kraemer *et al.*[14] also reported this same acute response after the performance of the resistance training in women. These authors believe that probably the increase on the cortisol concentration will occur at the recovery period, indicating a delay in the post-training cortisol secretion in women. Marx *et al.*[4], just like us, demonstrated reduction in the circulating cortisol after eight weeks of resistance training in women at rest situation. The repetition of the physiological stress imposed by the exercise performed in the physical training is correlated to the alteration in the sensibility of the hypothalamic-pituitary-adrenal axis[1,5]. In some studies, trained individuals demonstrated increase in the sensibility of the hypophysis and the adrenal cortex to the corticotrophin-releaser hormone (CRH), while, in other studies, a decrease was reported[19]. As demonstrated by Luger *et al.*[15], elite runners demonstrated lessening of the adrenocorticotropic hormone (ACTH) and cortisol responses to the hexogen administration of CRH. Probably, the cortisol reduction observed after eight weeks of MS training in rest situation, as previously observed[4,14], would be related to the modulation induced by the hypothalamic-pituitary-adrenal axis[15].

As in our study, Marx *et al.*[4] also observed increase in the T:C ratio after eight weeks of training during rest (table 4). However, unlike our results, these authors verified increase in the total circulating testosterone concentration. However, this testosterone increase response is questionable. The testosterone concentration in many other studies also remained unchanged[20,21]. Bosco *et al.*[22] recently proposed an association between the testosterone concentration and the reduction of the neural activity during a high-intensity resistance training session performed in men. Based on these results, these authors concluded that the testosterone (in adequate concentrations) could compensate the fatigue of fast fibres (present as the training session goes on), thus guaranteeing a lower neuromuscular efficiency.

Our results show increase in the T:C ratio (table 4), indicating that the metabolic condition induced by the MS method is favorable to the protein anabolism[23,24]. After eight weeks of resistance training, the participants presented a significant increase in this relation, fact that may be explained mainly by the reduction in the cortisol concentration. The reduction in the circulating cortisol after the strength training has been reported for both men[14,25] and women[4,14]. This drop may be relevant for inhibition of the protein catabolism and furtherance of proteins aggregation through the reduction of their degradation. This response may be especially important for fibres type I, which depend more on the reduction of the protein degradation as primary mechanism, responsible for their hypertrophy[26].

Although no significant alterations had been detected in the functional and body composition parameters, this fact does not discard the influence caused by the hormonal alterations. Probably, the structural adaptations (synthesis and aggregation of contractile proteins) that would enable the gain of power and muscular strength need eight more weeks to occur. Possibly, the long-term positive feature of the T:C ratio will provide the emergence and development of such adaptations.

The reduction in the testosterone concentration, along with the increase in the cortisol concentration, occurs in periods of exhausting training. Currently, it is believed that the concentration of testosterone into cortisol (T:C ratio) would be a physiological indicative of overtraining in which the individual is exposed to, but it does not necessarily means overtraining syndromes[9,23,24]. Viru and Viru[9] emphasize that this change is clearly an overreaching indicative, but not an overtraining indicative. The reduction on the post-training T:C ratio emphasized in our study, after eight weeks of training using the MS method, suggests that this stimulus has represented a punctual intense overload to the organism. However, the positive reestablishment of the T:C ratio in rest situation after eight weeks of training suggests the occurrence of the super-compensation mechanism.

Although our results indicate that the MS method is capable of modulating the T:C ratio in women, it is worthy emphasizing that the reduced number of participants (n = 5) and the short duration of the present study (eight weeks) are limiting factors for definitive conclusions. Other limitation of the present study was the absence of a control group. Unquestionably, further studies are necessary in order to verify the influence of different strength training protocols on the stress imposed to the organism and its subsequent capacity of long-term response-compensation.

CONCLUSION

Our data reinforce the idea of the importance of the correct control of the acute variables related to the prescription of resistance training. We believe that it is vital to establish which training protocols present the potential to promote positive adaptations without the establishment of harmful conditions. The decrease in the T:C ratio after the training session, observed at the end of the study, suggests that the resistance training method used represents an intense stimulus to the organism. However, the recovery of the T:C ratio evidences, in the rest situation after eight weeks of training, the occurrence of the super-compensation mechanism. Through this result, we verify that the MS method, at the end of eight weeks, seems to induce a hormonal condition favorable to the protein anabolism in the rest situation.

ACKNOWLEDGMENTS

To the Fapesp for the financial support and to the academy Companhia Athletica Unidade SP-Market, São Paulo.

All the authors declared there is not any potential conflict of interests regarding this article.

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