HORMONAL RESPONSES TO CONCURRENT STRENGTH AND ENDURANCE TRAINING WITH DIFFERENT EXERCISE ORDERS

EDUARDO LUSA CADORE,1 MIKEL IZQUIERDO,2 MARIAH GONÇALVES DOS SANTOS,1 JOCELITO BJOLDO MARTINS,1 FRANCISCO L. RODRIGUES LHULLIER,1 RONEI SILVEIRA PINTO,1 RODRIGO FERRARI SILVA,1 AND LUÍZ FERNANDO M. KRUEL1

1Exercise Research Laboratory, Physical Education School, Federal University of Rio Grande do Sul, Porto Alegre, Brazil; and 2Department of Health Sciences, Public University of Navarre, Navarre, Spain

ABSTRACT

Cadore, EL, Izquierdo, M, dos Santos, MG, Martins, JB, Lhullier, FLR, Pinto, RS, Silva, RF, and Kruel, LFM. Hormonal responses to concurrent strength and endurance training with different exercise orders. J Strength Cond Res 26(12): 3281–3288, 2012—The purpose of this study was to examine the influence of the intrasession sequencing of concurrent strength and aerobic training on the acute testosterone (TT) and cortisol (COR) responses. Ten recreationally strength-trained young men (23.5 ± 0.9 years) performed 2 exercise interventions: aerobic-strength (AS) and strength-aerobic (SA), which consisted of 30 minutes of aerobic exercise on a cycle ergometer at 75% of maximal heart rate and 3 sets of 8 repetitions at 75% of 1 repetition maximum (1RM) in 4 strength exercises. Maximal heart rate was determined using a maximal incremental test on a cycle ergometer. Blood samples were collected before, between exercise modalities, and immediately after the concurrent training sessions to determine basal and acute total TT and COR concentrations. There were significant increases in TT after the first modality in both exercise orders (p < 0.05). However, the TT level remained significantly higher than the resting levels after the second exercise modality only in the AS (p < 0.05) which resulted in a significant higher relative total change after the complete concurrent training session compared with SA (p < 0.05). Regarding COR, there were significant increases after the first modality in both AS and SA orders (p < 0.05), but the COR returned to resting levels after the second modality in both AS and SA interventions. During AS and SA, the change observed after the first modality performance was greater than that after the second in both hormones. The present results suggest that the TT response is optimized after the AS order, whereas both AS and SA produced similar hormonal levels at all time points. However, it is important to state that the present results should be applied only when short duration and moderate intensity aerobic training is performed.

KEY WORDS testosterone, cortisol, strength training, aerobic exercise, endocrine responses

INTRODUCTION

Strength training is a powerful stimulus to the acute increase in concentrations of circulating testosterone (TT) and cortisol (COR). Several studies have investigated the influence of factors related to the training session in the acute hormonal responses to strength training, such as relative intensity to the maximum load (% of 1 repetition maximum [1RM]) (37), number of sets (39), interval length (31), muscle mass involved (21), and type of muscle contraction (28). These studies attempt to understand what factors may produce a hormonal response that favors the chronic adaptations to training, because there is some evidence to suggest that the hormonal response to individual training sessions is related to the magnitude of chronic neuromuscular adaptations to strength training (2,8,22). Although these factors have a critical influence on the magnitude and duration of the acute response of TT and COR to strength training (2,21,29), there is little data available in the literature regarding the influence of performing aerobic exercise combined with strength training on the acute response of TT and COR. Nevertheless, the simultaneous performance of both types of exercise (aerobic and strength) can generate a higher metabolic demand, resulting in a greater increase in COR, which could negatively influence the release of TT during the training session (6,13).

Simultaneous performance of strength and aerobic training has been called concurrent training (4,5,10,14,20,27). Some
Hormonal Responses to Concurrent Training

studies have shown that aerobic training may negatively influence the development of strength that would normally result from strength training, and this effect has been called “interference effect” (4,10,20,27,32). This interference effect may be associated with the high volume and intensity of training and be explained by factors such as low muscle glycogen leading to a chronic catabolic state, antagonistic protein synthesis signaling (3), which ultimately interferes with the magnitude of muscle hypertrophy, especially in type I fibers (4); impairment of neural adaptations resulting from resistance training (10,20); and peripheral fatigue resulting from aerobic training which ultimately impairs strength performance (34).

The interference associated with the chronic catabolic state may occur when a large volume of training is performed (4,5,32) which can lead to a steep rise in the resting levels of circulating COR, a hormone associated with protein catabolism, and a consequent imbalance among the anabolic hormones (i.e., TT, growth hormone [GH]) which stimulate protein synthesis and catabolic hormones (i.e., COR), thus producing an unfavorable environment for the development of muscle mass (4,5,32). In fact, some studies have observed the occurrence of the interference effect on developing strength and muscle mass, parallel to the increase in resting COR concentrations (4,5,32). In general, the role of hormone concentrations in the interference effect has been investigated by assessing the circulating TT and COR at rest (4,5,10,32). To the best of the author’s knowledge, only 1 study has investigated the acute hormonal responses to a concurrent training session. Goto et al. (18) investigated the effect on hormonal responses of combining in the same training session an aerobic training protocol before a resistance exercise or perform resistance exercise alone. Although these authors found that the aerobic exercise suppressed the GH response to resistance exercise, aerobic exercise was found to have no influence on the response of COR or TT to resistance exercise. However, the exercise protocols used in the study by Goto et al. (18) resulted in no significant increase in these hormones. Moreover, the influence of manipulating the order of the modalities (i.e., strength and aerobic) on the pattern of acute responses of TT and COR in a concurrent training session remains to be elucidated.

Because the performance of both modalities is very common by recreational exercise practitioners that aims to improve both muscle mass and cardiorespiratory fitness, it is important to determine the influence of the simultaneous performance of aerobic training and strength training on the acute hormonal response to strength training adaptations (12,33), especially when performing short volume and moderate intensity of aerobic and strength training interventions. Moreover, determining the best order in which to perform the training modalities during concurrent training, strength-aerobic (SA) or aerobic-strength (AS), and so optimizing a more anabolic hormonal response, could be an important factor in the prescription of concurrent training. Because of the lack of data in the literature, regarding the effect of the order in which the types of training are performed during concurrent training, the purpose of this study was to investigate whether this factor influences the acute response of TT and COR during a concurrent training session. Our hypothesis is that aerobic exercise performed before resistance exercise could negatively affect the acute TT responses.

METHODS

Experimental Approach to the Problem

To investigate the effect of exercise order manipulation on the acute hormonal responses to concurrent training, the subjects attended the laboratory sessions on 5 different occasions. On the first day, the subjects signed the written consent form, and their anthropometric characteristics were evaluated. On the second day, the 1RM test was performed to establish the reference to prescribe the strength training intensity. On the third day, a maximal incremental test was performed to determine the heart rate at maximal aerobic workload (HRmax), as parameter to the intensity of aerobic exercise. On the last 2 days, the concurrent exercise protocols, in which the exercise-type order was manipulated, were performed randomly, with 1 week of rest between them. All the subjects performed the strength and aerobic maximal tests at the same time of the day (between 8 and 10 AM) and the 2 exercise orders at the same time of the day (between 8 and 9 AM) throughout the period of the study.

Subjects

Ten young strength-trained men (mean ± SD: 23.5 ± 0.9 years), who were engaged in regular (4–6 times a week) and systematic training program for at least 3 months, volunteered for the study after completing an ethical consent form. The subjects were carefully informed about the design of the study with special information given regarding the possible risks and discomfort related to the procedures. The study was approved by the Ethics Committee of the Federal University of Rio Grande do Sul, and it is in accordance with the Helsinki Declaration. Exclusion criteria included any history of neuromuscular, metabolic, hormonal, and cardiovascular diseases. The subjects were not taking any medication with influence on their hormonal and neuromuscular metabolism and were advised to maintain their normal dietary intake throughout the study. The physical characteristics of the subjects are shown in the Table 1. Body mass and height were measured using an Asmed analog scale (resolution of 0.1 kg) and an Asmed stadiometer (resolution of 1 mm), respectively. Body composition was assessed using the skinfold technique. A 7-site skinfold equation was used to estimate body density (26), and body fat was subsequently calculated using the Siri equation (23).
Maximal Dynamic Strength

Maximal strength was assessed using the 1RM in free-weight bench press, smith machine squat, lat pull-down, and bilateral knee extension exercises (World, Porto Alegre, Brazil). One week before the test day, the subjects were familiarized with all the procedures. On the test day, they warmed up for 5 minutes on a cycle ergometer and performed specific movements for the exercise test. Each participant’s maximal load was determined in a maximum of 5 trials. A 4-minute rest was allowed between trials, and the performance time for each contraction (concentric and eccentric) was 2 seconds, controlled with an electronic metronome (KORG, Melville, NY, USA). The test-retest reliability coefficients (ICC) were >0.97.

Maximal Aerobic Test

Heart rate at maximal aerobic workload was determined using an incremental test on a cycle ergometer. The participants began the test cycling at a 50-W load for 2 minutes, and this was increased by 25 W each 1 minute, while a cadence of between 70 and 75 rpm was maintained, until the participants claimed exhaustion or they were no longer able to maintain a cadence of over 70 rpm. The $W_{max}$ (in watts) was calculated using the formula: $W_{max} = W_{com} + (\tau/60)\Delta W$, where $W_{com}$ is the load at the last stage completed, $\tau$ is the time at the last incomplete stage, and $\Delta W$ is the load increment in the last stage (25 W) (25). The heart rate at maximal workload was measured using a Polar T61 transmitter and a FS1 wrist monitor (Polar, Kajaani, Finland). The test-retest reliability coefficient (intraclass correlation coefficient [ICC]) was 0.88.

**Concurrent Training Protocols**

The performance of the different exercise orders, SA or AS, were determined randomly. During each experimental protocol, the subjects were advised to hydrate at will. Before the concurrent training sessions, the subjects performed a 5-minute warm-up at a comfortable cadence and performed specific muscle stretching and a specific warm-up, with 1 set of 25 repetitions with very light loads for the upper and lower body. Strength training lasted approximately 30 minutes and consisted of 3 sets of 8 repetitions at 75% of 1RM with 90 seconds of resting between sets. This intensity was chosen because it is commonly used by recreational strength training practitioners to promote muscle hypertrophy (70–85% of 1RM) (39). Strength exercises were performed always in the same order: bench press, squat, lat pull-down, and knee extension. During the aerobic training, the subjects performed 30 minutes of continuous exercise on a cycle ergometer at 75% of maximal heart rate. The total concurrent training session lasted approximately 1 hour. The total absolute load and the total number of repetitions and sets in both exercise orders were exactly the same (Table 2).

**Blood Collection and Analysis**

Blood was obtained between 8 and 9 AM, after 8 hours of sleep, 12 hours of fasting, and 2 days with no physical training session. The time of blood collection was chosen because of its use in many studies conducted with these procedures for the control of the circadian hormonal range (7,9,32). The subjects sat in a slightly reclined position for 15 minutes, and after that, 10 ml of blood was drawn from the antecubital vein before, between exercise modalities (strength and aerobic), and immediately after the concurrent training session with similar techniques. After collection, the blood was maintained at an ambient temperature for 45 minutes and then centrifuged for 10 minutes at 2,000 rpm, and serum was removed and frozen at −20°C for later analysis. With this blood sample, concentrations of total TT (nanomoles per liter) and COR (nanomoles per liter) (MP Medicals, Twinsburg, OH, USA) were determined in duplicate, using radioimmunoassay kits. From these values, it was possible to calculate the

---

**Table 1. Physical characteristics.***

<table>
<thead>
<tr>
<th></th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>23.4 ± 0.9</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>174.8 ± 4.9</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>77.5 ± 4.8</td>
</tr>
<tr>
<td>Fat mass (%)</td>
<td>15.8 ± 2.7</td>
</tr>
<tr>
<td>Lean mass (%)</td>
<td>84.2 ± 2.7</td>
</tr>
<tr>
<td>Bench press 1RM (kg)</td>
<td>92.9 ± 16.3</td>
</tr>
<tr>
<td>Squat 1RM (kg)</td>
<td>113.6 ± 8.6</td>
</tr>
<tr>
<td>Lat pull-down 1RM (kg)</td>
<td>87.4 ± 13.4</td>
</tr>
<tr>
<td>Knee extension 1RM (kg)</td>
<td>120.0 ± 18.4</td>
</tr>
<tr>
<td>Maximal heart rate (b·min⁻¹)</td>
<td>187.2 ± 5.35</td>
</tr>
</tbody>
</table>

*1RM = 1 repetition maximum.

**Table 2. Exercise protocols characteristics (mean ± SD).**

<table>
<thead>
<tr>
<th></th>
<th>Strength-aerobic</th>
<th>Aerobic-strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bench press (kg)</td>
<td>64.8 ± 10.9</td>
<td>64.8 ± 10.9</td>
</tr>
<tr>
<td>Squat (kg)</td>
<td>79.8 ± 6.1</td>
<td>79.8 ± 6.1</td>
</tr>
<tr>
<td>Lat pull-down (kg)</td>
<td>60.9 ± 9.5</td>
<td>60.9 ± 9.5</td>
</tr>
<tr>
<td>Knee extension (kg)</td>
<td>83.9 ± 12.8</td>
<td>83.9 ± 12.8</td>
</tr>
<tr>
<td>Total load (kg)</td>
<td>289.1 ± 33.9</td>
<td>289.1 ± 33.9</td>
</tr>
<tr>
<td>Heart rate during aerobic exercise (b·min⁻¹)</td>
<td>140.0 ± 4.0</td>
<td>142.0 ± 5.0</td>
</tr>
</tbody>
</table>
TT/COR ratio. To eliminate interassay variance, all the samples were analyzed within the same assay batch, and all intraassay variances were ≤6.3%. Antibody sensitivities were 0.7 nmol L$^{-1}$ for TT, and 1.4 nmol L$^{-1}$ for COR. The test-retest reliability coefficients (ICC) were 0.85 for COR and 0.94 for TT.

### Statistical Analyses

Results are reported as mean ± SD. Comparisons between different exercise orders were assessed using a 2-way analysis of variance with repeated measures (order × time). When a significant $F$ value was achieved, Fisher’s least significant difference (LSD) post hoc procedures were used to locate the pairwise differences. The relative range of the hormones after the concurrent training session was compared between exercise orders by using Student’s paired $t$-tests. Also, Pearson’s product moment correlation test was used to verify the associations between the variables analyzed. The sample size was calculated using the GPOWER program (version 3.0.1) that determined a sample of $n = 10$ subjects, with a statistical power of >85% in all variables. Significance was accepted when $p \leq 0.05$.

### Results

There were no significant differences in the TT and COR resting levels between the different experimental days (Table 3).

Regarding the absolute changes in the TT, there were a significant time-effect and time vs. order interaction ($p < 0.01$) (Figure 1). Testosterone increased after strength exercise was performed independently of interventions (in both SA and AS protocols). After AS, the TT value remained significantly higher ($p < 0.01$) compared with that recorded at the resting levels, whereas in the SA intervention, TT returned to the resting levels.

Moreover, in the first exercise modality (strength or aerobic exercise) of both interventions (SA or AS protocols), the acute relative TT change was higher than that observed after the second one (SA: 22.3 ± 23.5% vs. –12.9 ± 17.8% and AS: 31.8 ± 40.5% vs. 7.6 ± 18.2%; $p < 0.05$). In addition, the total

### Table 3. Hormonal concentrations at rest and after the exercise protocols (mean ± SD).*

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Mid</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strength</td>
<td>Aerobic</td>
<td>Strength</td>
</tr>
<tr>
<td>TT (nmol L$^{-1}$)</td>
<td>18.2 ± 3.8</td>
<td>21.7 ± 3.7†</td>
<td>18.7 ± 4.0‡</td>
</tr>
<tr>
<td>COR (nmol L$^{-1}$)</td>
<td>584.0 ± 114.8</td>
<td>629.3 ± 102.7†</td>
<td>610.5 ± 106.0</td>
</tr>
</tbody>
</table>

*TT = total testosterone; COR = cortisol.
†Significant difference from baseline values ($p < 0.05$).
‡Significant difference between midtime point and posttime point ($p < 0.05$).
relative change of TT (after the complete concurrent training session) was significantly higher in AS compared with the SA order (41.4 ± 47.8% vs. 3.3 ± 14.7%; p < 0.01).

Comparing the hormonal responses with the same modality in the different orders, the relative TT response was higher after aerobic exercise in the AS compared with that in the SA (p < 0.01). Relative TT response was also higher after strength exercises in the SA compared with that of the AS (p < 0.05). Furthermore, the relative TT change after the second modality was significantly higher in the AS than in the SA order (p < 0.05).

In the COR levels, there was a significant time effect (p < 0.05), with absolute increases being observed after the first exercise modality (strength or aerobic exercise) in both interventions (SA or AS protocols) (Figure 2). After the second exercise modality (strength or aerobic exercise) in both AS and SA, COR concentrations returned to resting levels. In addition, no differences between the exercise orders were found in the relative total change of COR before and after total interventions (AS: 12.6 ± 21.5% and SA: 8.2 ± 27.8%). Notwithstanding, independent of the type of exercise modality (strength or aerobic exercise), in both interventions (SA or AS) relative changes during the first exercise modality were significantly greater than the second one (SA: 10.6 ± 23.6% vs. −2.1 ± 14.5%; and, AS: 11.5 ± 14.5% vs. 1.1 ± 14.1%; p < 0.05).

A significant time effect in both AS and SA (p < 0.05) was observed in the TT/COR ratio. Independent of both interventions (SA or AS), the increases observed after the first exercise modality (strength or aerobic exercise) were similar, with no differences between the mid and posttime points (Figure 3).

During the SA, significant negative correlations were observed between resting levels of COR and corresponding individual total changes of TT (r = −0.73, p = 0.016); COR and TT concentrations at midtime point (r = −0.78, p = 0.007); COR and TT concentrations after the complete intervention (at posttime point) (r = −0.80, p = 0.005); and significant negative correlations between TT changes after the strength exercise and TT changes after the aerobic training (r = −0.85; p = 0.002).

In the AS, significant negative correlations were also observed between resting levels of COR and corresponding individual TT changes after aerobic exercise (midtime point) (r = −0.76, p = 0.011); and with corresponding individual TT changes after strength exercise (posttime point) (r = −0.87, p = 0.001).

**DISCUSSION**

To our knowledge, this is the first study that examines the influence of manipulating the order of the exercises modalities (i.e., strength and aerobic) on the pattern of acute responses of TT and COR in a concurrent training session. The main results of this study showed that regardless of the order of the modalities performed (SA or AS intervention) during a concurrent training session, the TT and COR responses are always higher after the first exercise modality (strength or aerobic exercise) than they are in the second. Moreover, the magnitude of the total TT response in the AS session was greater than that observed after the SA session, suggesting that the order of the exercise modalities (strength or aerobic exercises) can influence the acute TT response to the training session. Furthermore, there were negative correlations between COR levels and the magnitude of the TT responses, indicating that those subjects with lower levels of COR tend to have higher acute TT increases, and, therefore, COR may have an inhibitory effect on TT production.

In a study performed by Goto et al. (18), the GH response to strength training was suppressed because of the prior performance of aerobic training. However, no differences were observed in the concentrations of TT and COR induced by strength training, with and without prior aerobic training performance. Nevertheless, in that study, the concurrent training sessions did not provide sufficient stimulus to induce increases in TT and COR. The differences between the results obtained by Goto et al. (18) and those of this study may be because of the lower intensity of the aerobic training in the former compared with the latter (50 vs. 75% of HRmax, respectively), lower volume of strength training (2 vs. 4 exercises, respectively), and the time at which the measurements were taken after the exercise protocol, 10 minutes in the study by Goto et al. (18) and immediately after the protocol in this study.

When analyzing the second part of each training session, our results are in line with some results that compared the stimulus of strength and aerobic training on hormonal response. Some authors have shown that strength training seems to stimulate greater increases in TT and COR than aerobic training does (11,40), which can be explained by the powerful influence of the anaerobic glycolytic pathway in stimulating acute hormonal increases in response to exercise.
Hormonal Responses to Concurrent Training

In this study, this pattern only became evident in the second exercise of the training sessions, in which strength training resulted in a greater stimulus for TT when compared with aerobic training. The strength training session used in this study, in which the glycolytic pathway is predominant, has a great potential for stimulating TT. Therefore, there may be a direct stimulation of lactate in the testes, as demonstrated in a study performed by Lu et al. (35), who observed a correlation between the increase in TT and increase in lactate during an incremental protocol in rats. Furthermore, these authors demonstrated in vitro that the direct infusion of lactate in the testes resulted in a dose-dependent increase in TT. Thus, the aerobic exercise, after a session of strength training, may not have been able to further stimulate or maintain TT levels, because the intensity and possibly the metabolic impact were not maintained, which resulted in a lower total variation in TT levels after SA, when compared with the AS order. Another hypothesis that may explain the return to resting TT levels during the second modality in the SA order is the possible use of lactate accumulated during strength training as an energy substrate during the aerobic training (47), which would decrease the stimulus for TT. However, lactate concentrations were not measured in this study, so this hypothesis remains speculative.

It should be also considered that the androgen receptor (AR) content was not measured in this study, and it is possible that changes in the circulating TT might have had an influence of the increased hormone-receptor interaction. Thus, the decrease in TT from mid to postexercise in the SA order might have been a result of increased receptor binding and not a decrease in secretion. In fact, it has been demonstrated that strength-trained subjects have increased numbers of ARs and also that strength training bout stimulates the acute increases in AR content (43). However, this hypothesis should be considered with caution and remains speculative.

When the aerobic exercise was performed first during the AS intervention, it may have been sufficient to stimulate the TT of the subjects in this study, who are strength trained, but not aerobically trained. In fact, it has been demonstrated that the training status (1,9,29,40), and the type of training undertaken by individuals influence the hormonal response. In a study by Tremblay et al. (39), the increase in anabolic hormones was shown to be greater with strength training in strength-trained subjects, compared with that in aerobically trained individuals, whereas aerobically trained subjects had higher hormonal responses to aerobic exercise than strength-trained subjects had (40). Thus, one may suggest that with aerobically trained subjects, it is possible that the hormonal-response pattern to aerobic exercise could be different, possibly with that the subjects presenting higher values in response to the short duration aerobic exercise performed in this study (40), which would result in a different overall response to the total concurrent training session. Furthermore, the hormonal response to aerobic training can be explained by increased sympathetic activity during exercise (16) or even by greater vasodilation in the testes stimulated by increased release of nitric oxide resulting from the exercise (38). Thus, it is probable that aerobic trained subjects would perform the aerobic exercise in a higher absolute intensity, which would result in higher sympathetic activity and possibly altering the overall endocrine response (9). However, only recreational strength-trained subjects participated in this study, and this hypothesis remains speculative. Moreover, this speculation should not be applied when longer aerobic exercise is performed, because it has been demonstrated that TT can be suppressed in response to long duration aerobic exercise, especially during overtraining syndrome (32,33,41).

Previous studies have shown a correlation between the acute response of TT to single training sessions and the magnitude of the increase in strength, power, and muscle mass resulting from chronic strength training adaptations (1,2,9,33). Besides the important role of TT in the synthesis of contractile proteins (19), and in the synthesis of neurotransmitters related to strength production (30), the increase in TT in response to strength training seems to be related to the magnitude of the increase in the number of ARs in human cells (43). Other studies in animal models demonstrated that the amount of ARs plays an important role in the magnitude of muscle hypertrophy (24). Thus, the manipulation of the various factors related to the training session that influence acute hormonal responses, such as volume and intensity (39), time interval (31), and muscle mass involved (21) can optimize the increase in TT in response to the training session. Regarding aerobic training, although the importance of the anabolic hormonal response is not well known, TT and COR seem to be more responsive to higher intensity (15) and longer duration of exercise (41). Thus, the short duration and moderate intensity aerobic protocol performed in this study might have been a limited stimulus to maintain the TT elevated after the strength training bout in SA.

With respect to circulating COR, both training sessions caused a significant increase after the first exercise, with levels returning to normal after the end of the training sessions. Cortisol, which is responsible for 95% of glucocorticoid activity, is a catabolic hormone responsible for lipid and protein degradation and subsequent mobilization of energy substrate during exercise (42). Besides the metabolic impact related to time and exercise intensity (15,41), psychological stress may be responsible for an acute increase in COR (36). The fact that the subjects in this study were strength trained may explain the absence of modifications related to the longer duration of exercise, regardless of the order of execution of the modalities. Indeed, it has been demonstrated that the training status directly influences the magnitude of the adrenal cortical response with trained individuals presenting a significantly lower acute response when compared with the untrained (9,30).
The purpose of this study was to investigate whether there are acute physiological differences in the response to different orders of exercise during concurrent training, to elucidate whether the order in which the exercises are performed influences the hormonal response when the volume and intensity of the exercises modalities are kept equal. The results of this study suggest that, if the objective is to optimize the response of TT to a concurrent training session, aerobic exercise before strength training can keep TT levels elevated for longer. On the other hand, caution is to be exercised in the interpretation and applicability of the results, because performing aerobic training before strength training can generate residual fatigue and impair the capacity to produce strength (34). In addition, although the AS session caused a higher and more persistent increase in total TT, both training sessions caused an increase in the TT/COR ratio. Nevertheless, the acute TT/COR ratio seems to be a very simplistic variable as an indicator of the balance between anabolism and catabolism (33).

In this study, inverse correlations were observed between the initial levels of COR and the acute response of total TT ($r = -0.73$ to $0.80, p < 0.05$). Our results are in agreement with those of the study by performed Brownlee et al. (6), who observed an inverse correlation between the levels of COR and TT in response to aerobic exercise on a cycle ergometer and suggested COR may have an inhibitory effect on TT production. In fact, some studies have shown that the use of pharmacological COR has an inhibitory effect on the steroidogenic process in Leydig cells, via enzymatic inhibition (13) or by eliminating cyclic adenosine monophosphate (cAMP) production (42). Our findings are important because they suggest that the acute response of TT may be impaired in individuals with high COR levels, which could result in a limitation to the magnitude of the chronic adaptations to strength training, based on the importance of these levels for the increase in strength and muscle mass (2).

In conclusion, the results of this study showed that the manipulation of the order in which the types of exercise are performed during a concurrent training session can influence the magnitude of the acute TT response, with the AS session showing a greater relative increase after the training session, which was not observed in COR. Based on the relationship, suggested in the literature, between acute hormonal responses and chronic neuromuscular adaptations to strength training, this could be positive for the optimization of muscle hypertrophy in the long term. However, the extent of the importance of this response in chronic adaptations to concurrent training remains speculative and further studies employing different volumes and intensities of training, and different populations are needed to determine whether the response observed in this study is, in fact, a pattern. Moreover, caution is to be exercised to interpret our results because, although the different concurrent exercise orders resulted in different acute TT responses, it did not produce differential hormone levels between interventions. Furthermore, the AR content was not measured in this study and the hormone-receptor interaction might have influenced the present results.

**Practical Applications**

Based on the relationship between acute hormonal responses and chronic neuromuscular adaptations to strength training, the present results are important because it suggests that moderate intensity, short duration aerobic exercise did not affect negatively acute TT responses to resistance exercise. In addition, it appears that performing the AS modality order might keep acute TT elevations for a longer period of time compared to the inverse order. Notwithstanding, it should be noted that only recreational strength-trained subjects participated in this study and it not possible to extrapolate these results to aerobic trained and sedentary subjects.

**Acknowledgments**

The authors specially thank CAPES and CNPq government associations for their support to this project. The authors are also grateful to all the subjects who participated in this research and made this project possible.

**References**

Hormonal Responses to Concurrent Training


