Research Article

The Simulation Effects of Mountain Climbing Training on Selected Endocrine Responses

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Abstract

The simulation effects of mountain climbing exercise training on plasma testosterone, cortisol and luteinizing hormone (LH) levels were examined in ten recreational mountain male climbers. Subjects underwent a simulating mountain climbing exercise training 3 times a week for a total of eight weeks before an expedition to Mount Muztag Ata (7546 m, Xingian, China). During training, each subject carried a 40 kg back pack while walking on a treadmill at a speed of 1.9 mph for 60 min at sea level. Subjects completed an incremental treadmill test to exhaustion prior to training, after training, and one week after returning from Mount Muztag Ata. Blood samples were collected from antecubital vein at rest and at 5, 60, and 120 min post testing to determine the plasma testosterone, cortisol and LH levels. The basal plasma testosterone and cortisol concentrations were lower in both post-training and after-climbing conditions compared with that in the pre-training condition ($p<0.01$). The basal plasma LH concentration was remained unchanged after training and after the mountain climbing compared with levels measured in the pre-training phase. No correlation could be established between plasma LH and testosterone level. These results suggest that an eight-week period of mountain climbing training protocol may be beneficial in maintaining normal endocrine function during and after high altitude mountain expedition. Our results also indicate the decrease of plasma testosterone was LH independent.

Key Words: treadmill training, testosterone, cortisol, LH

Introduction

Evaluation of serum hormones during or after prolonged physical activity and/or training has received considerable attention due to its implications for general adaptive mechanisms and for physical condition (10, 11, 12, 20). However, a large individual variability has been observed in the changes of cortisol and testosterone under conditions of physical exertion (7, 20, 21). Testosterone is a steroid hormone produced and secreted by the Leydig cells in testes, which has both anabolic and anticatabolic effects on muscle tissues (20, 22). Cortisol is a steroid hormone released by the adrenal cortex and has catabolic effects on muscle tissues (13, 15). Cortisol and testosterone have been reported to be changed significantly when training is intensified (1, 22). Serum testosterone concentration has been shown to decrease after prolonged strenuous activities (20, 23). Decreases in follicular stimulating hormone (FSH) and luteinizing hormone (LH) secretion following prolonged physical activity have also been reported (14). The response of cortisol to intensified training is not consistent in the literature (7, 10, 13, 15). For example, cortisol has been reported to be elevated following a two week period when training intensity was increased two-fold (13), but has also been reported to remain unchanged or even decreased when similar increases in training load were implemented (7, 15).

During high mountain expedition, both hypoxia and altitude may result in abnormalities in endocrine function (2, 9, 18). Studies on endocrine function of testis and its control by the pituitary hormones are not only scanty but also inconclusive (18).

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The present study was carried out to determine the effect of simulating mountain climbing exercise on plasma testosterone, cortisol, and LH levels, and to determine the effect of training on high altitude mountaineering.

Materials and Methods

Subjects

Ten active male subjects (aged 21 - 41 years old) gave informed consent following clearance to conduct the study from the Committee of Human Rights in the National Yang-Ming University. The subjects represented a recreational mountain climbers. None of the subjects had a history of hormonal medication, and all were healthy on physical examination. Some physical characteristics of the subjects are summarized in Table 1.

Testing Sessions

Subjects completed an incremental treadmill test to exhaustion, beginning with 5 min exercise on a treadmill at 1.7 mph and at 10% grade. Progression was accomplished by increasing the treadmill speed and slope every 5 min according to the Bruce protocol (4). The test concluded when the subject could no longer complete a 5-min exercise period. The test session was implemented before and after the total 8-week of training regimen. A follow-up test session was also conducted one week after the subjects returned from climbing Mount Muztag Ata (7546 m, Xingian, China).

Training Sessions

The training was administered 3 times a week for a total of eight weeks. The training program was designed to simulate mountain climbing activity. Each subject carried a 40 kg back pack while walking on a treadmill at sea level. Throughout the training, the treadmill speed was kept constant at 1.9 mph. The slope of the treadmill, however, was changed between the two slopes, 10% and 15%, alternatively for every 5 min during a training session. Each training session lasted for 60 min.

The Expedition to Mount Muztag Ata

On day 1, the subjects left Taipei for Urumuch City (Xingian, China) and reached the base camp (4300 m) 4 days after (day 7) their arrival in Urumuch. Two days later (day 9) they started for camp 1 (5300 m), 9 days after that (day 18) for camp 2 (6100 m), and one day later (day 19) for camp 3 (6700 m). Three subjects reached the summit (7546 m, day 20). After 5 days above 4000 m (day 25), they completed the expedition. Four days after leaving the base camp (day 29), all subjects returned to Urumuch for rest.

Blood Sampling

Prior to testing, each subject was required to rest quietly in an upright position for 5 min. A 30-ml blood sample was collected from the antecubital vein at rest and at 5 min, 60 min, and 120 min post testing. All samples were immediately chilled on ice following collection, centrifugation was conducted in a refrigerated centrifuge, and plasma samples were stored at -70°C prior to assay. Commercially available radioimmunoassay kits were used for the determinations of cortisol (Amersham, UK), LH (Incstar, USA), and erythropoietin (EPO) (Incstar, USA). The concentration of plasma testosterone was determined by RIA as previously described (16). With anti-testosterone No. W8, the sensitivity of RIA was 2 pg per assay tube. The intra- and inter-assay coefficients of variation were 4.1 % and 4.7 %, respectively.

Statistical Analysis

Two-way analysis of variance with repeated measures were used with the Shuffe's post hoc comparison to determine the significant mean differences. Significance was established at the $p<0.05$ level differences (19).

Results

Descriptive Characteristics

Table 1 provides the physical details of subjects employed in this study. Table 2 represents the hematological data of subjects. No significant changes in RBC count occurred during pre-training, post-training or after-climbing conditions. The level of hemoglobin (Hb) was not significantly different in post-training and after-climbing conditions from that in the pre-training condition. The level of hematocrit (Hct), however, was higher in subjects after-climbing than that measured during pre-training ($p<0.01$) or in post-training ($p<0.01$).

Plasma Hormone Levels

Figure 1 illustrates the plasma testosterone levels of our subjects. After the incremental treadmill testing, the level of plasma testosterone did not change significantly under pre-training, post-training or after-climbing conditions. The basal plasma testosterone concentration was lower under both post-training and

Table 1. Descriptive Characteristics of Experimental Subjects (n=10)

Variable	Means±SEM	(range)
Age, yr	29.8±2.1	(21-41)
Height, cm	172.1±1.9	(163.2-181.6)
Weight, kg	65.8±1.4	(60.9-76.5)
BMI*, kg/m^2	22.5±0.5	(20.3-24.9)

Values are means±SEM of 10 subjects.
*BMI: basal metabolic index

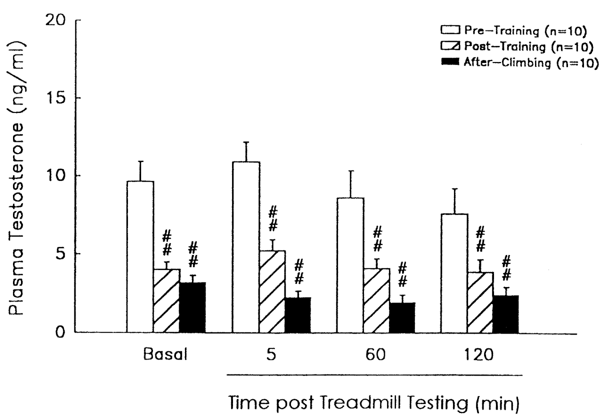

Fig. 1. Plasma testosterone levels measured at rest (basal) and at 5, 60, 120 min post treadmill testing under pre-training, post-training and after-climbing conditions. ##, p<0.01 as compared with the pre-training.

Table 2. Hematological Data of Subjects (n=10)

	pre-training	post-training	after climbing
RBC ($\times10^6/\mu l$)	5.24±0.31	5.39±0.28	5.82±0.29
Hemoglobin (g/dl)	14.18±0.25	14.68±0.34	15.88±0.39
Hematocrit (%)	42.56±0.75	44.38± 0.93	$48.18\pm0.98^{**,++}$
Erythrpoietin (mU/ml)	12.0 ±2.3	10.5 ±1.1	6.7 ±1.1

Values are expressed as means±SEM.
**, p<0.01 compared with the pre-training; ++, p<0.01 compared with the post-training.

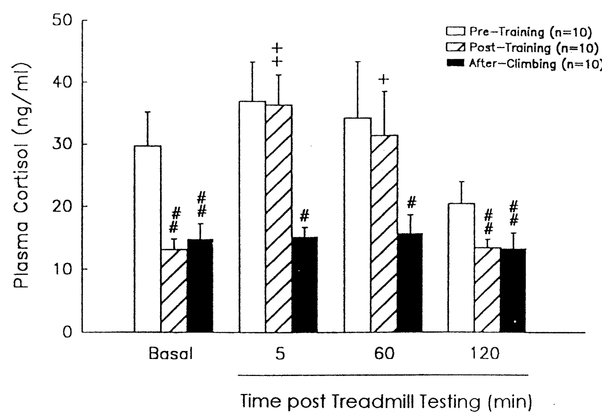

Fig. 2. Plasma cortisol levels measured at rest (basal) and at 5, 60, 120 min post treadmill testing under pre-training, post-training and after-climbing conditions. #,##, p<0.05 and p<0.01 as compared with the pre-training; +,++, p<0.05 and p<0.01 as compared with the basal level.

after-climbing conditions compared with that measured during pre-training (p<0.01). The basal plasma cortisol level was lower in subjects during post-training and after-climbing conditions compared to those during the pre-training conditions (p<0.01). The plasma cortisol level was significantly higher as measured at 5 (p<0.01) and 60 min (p<0.05) after exercise testing under post-training conditions (Fig. 2). When the subjects returned from the Mount Muztag Ata climbing expedition, the plasma cortisol level was not significantly changed in response to treadmill exercise testing measured at 5, 60, 120 min post testing (Fig. 2). The basal plasma LH concentration was not significantly changed after training or after the mountain climbing compared with the pre-training testing. There was no significant difference in plasma LH across time post testing under pre-training, post-training or after-climbing conditions (Fig. 3).

Relationships between Plasma Testosterone and LH Levels

Correlation between plasma LH and testosterone levels could not be established from our data (Fig. 4).

Discussion

The present results demonstrated that a mountain climbing simulation training exercise program resulted in a significant decrease in plasma testosterone and cortisol level, but not in plasma LH level. Therefore, the decrease of plasma testosterone was LH independent.

The level of hematocrit was increased after climbing the Mount Muztag Ata. However, we do not know the total magnitude of this variability since testing was not administered at the immediate end of the altitude stay but only after the return trip to Taipei. However, the plasma EPO level was lower (6.7±1.1 mU/ml), although not to a significant level, than that under the pre-training (12.0±2.3 mU/ml)

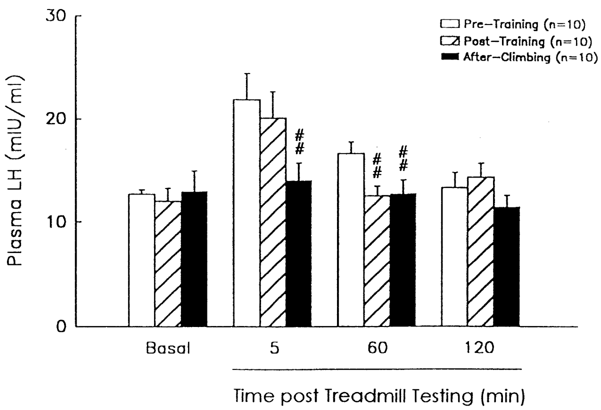

Fig. 3. Plasma LH levels measured at rest (basal) and at 5, 60, 120 min post treadmill testing under pre-training, post-training and after-climbing conditions. #,##, $p<0.05$ and $p<0.01$ as compared with the pre-training.

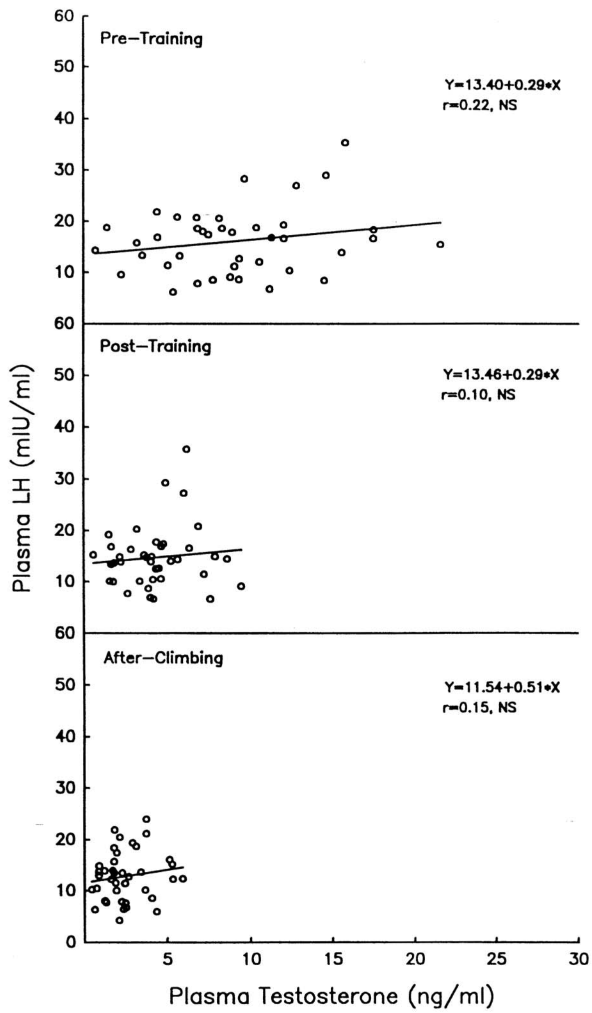

Fig. 4. Correlation between plasma LH and testosterone levels under pre-training (top), post-training (middle), and after-climbing (bottom) conditions.

and post-training conditions (10.5±1.1 mU/ml). The high hematocrit level after-climbing may be due to an inhibitory effect on the EPO production. This seems to correspond to the rather low plasma EPO concentrations measured in our subjects and other subjects after similar expeditions (3, 17).

Androgens have been reported to play an essential role in exercise training (8, 10, 20). During periods of intensive training lasting over several weeks, plasma testosterone concentration can periodically decrease (10, 20). After 8-week of simulating mountain climbing training, we found a decrease in plasma testosterone concentration which remained low even when the subjects returned from Mount Muztag Ata. Testosterone and free testosterone has been reported to decrease after 10 days of intensified running and cycling training (15, 23) which is consistent with our findings. However, high intensity resistance exercise has been reported to result in elevated concentrations of testosterone (11). A drop in urinary androgenic pool was observed during trekking and exposure to high altitude. Such hypoandrogenicity may play an important role in metabolic adaptations as well as in the mental state of the climbers (9).

According to our results, no change in plasma testosterone concentration was observed in 120 min post-test. Sutton et al. (20) found that serum androgens rose in response to maximal exercise but no response was obtained with submaximal exercise. While Kindermann et al. (13) reported 14% increase in plasma testosterone concentration following a maximal anaerobic running test to exhaustion, Wilkerson et al. (23) noted no change in plasma testosterone concentrations following 20 min running at various exercise intensities below that corresponding to VO2max. This discrepancy would support a role for exercise duration and intensity in modulating plasma testosterone concentrations. The protocol employed by Kindermann et al. (13) would appear to have been predominantly "lactic" while that of the Wilkerson et al. (23) and the current authors are largely "alactic" in nature. Mechanisms for the exercise induced changes in circulating testosterone concentrations are yet to be fully elucidated. Our findings of plasma testosterone concentration post an incremental treadmill test would suggest that the anabolic activities of testosterone are not affected by this exercise test protocol.

As cortisol is assumed to have an important role in adaptive reaction, many studies have focused on the role of increased cortisol release during exercise (1,13,15). A general observation has been noted that plasma cortisol levels rise progressively following heavy exercise (1) which can also be found in our subjects performing the treadmill exercise testing after 8 weeks of training. In our study, after simulating mountain climbing via exercise training, the maximal secretion was achieved within 60 min after termination of treadmill testing and returned to the basal level within 120 min. Elevated cortisol concentrations after exercise may contribute to muscle catabolism (13,15). There was no significant increase of cortisol during treadmill exercise testing in the pre-training conditions of our subjects, possibly because of high baseline cortisol levels. However, when the subjects were tested again after their return from Mount Muztag Ata, the exercise stress induced increase of cortisol was not significant. After 8 weeks of simulation mountain climbing training and after Mount Muztag Ata climbing, the basal level of cortisol was decreased compared to the pre-training condition. While lower plasma cortisol levels have been reported for trained subjects (1, 15), some authors tend to consider metabolic changes in trained subjects which adapt them to tasks which require cortisol release (1, 15).

Elias et al. (5) found a significant postexercise decrease in plasma LH concentration which reached its nadir 90 min post-test. We could not find a significant change in plasma LH levels post test in pre-training, post-training or after climbing condition. The reason for such differences are not immediately clear. A significant decrease in LH was observed on seventh day of stay at high altitude and the decreased levels were maintained until day 18 of observation (18). Within a week of return to sea level, the LH levels remained significantly lower (18). The authors then suggested that exposure to high altitude is associated with an impaired pituitary function (18). The LH level of our subjects, measured one week after they returned from Mount Muztag Ata, did not differ from that found during the pre-training conditions. This indicates that the training protocol may be beneficial in maintaining the normal pituitary function during exposure to high altitude.

The correlation between plasma LH and testosterone could not be established according to our data. Lack of association between androgens and LH has also been noted by other workers (14, 16). A rise in serum androgens was observed in the subjects performing maximal exercise test, such rise was independent of serum LH (14, 16, 20). LH is generally accepted as the pituitary gonadotrophin controlling testosterone secretion (14). However, in this study no changes in association with the testosterone decrease were observed in the post-training and after mountain climbing situations. The decrease of testosterone in response to 8-week simulating mountain climbing training was LH independent.

It has been proposed that the balance between catabolic and anabolic processes may be expressed by testosterone (T): cortisol (C) ratio (6, 21, 22). This ratio has also been suggested to be a useful index of training stress (1, 6, 22). A statistically insignificant change was observed in the T:C ratio in post-training (0.342 ± 0.054) and after climbing conditions (0.241 ± 0.027) compared with that of pre-training conditions (0.345 ± 0.058). This observation may correspond to the overall stability in the hormonal balance of the subjects throughout the period of training and mountain climbing. On the other hand, it may also indicate that the training was not too strenuous, with no noticeable symptoms of overtraining. Furthermore, our proposed simulating mountain climbing training program may reduce the hormonal and metabolic changes which have been associated with the mount climbing activity (2, 9).

We conclude that the treadmill exercise test may act as a physiological stimulus to elevations in plasma cortisol, but not testosterone and LH. The elevation of cortisol post-test is more marked after simulating mountain climbing training. A significant difference was observed in plasma testosterone which was independent of plasma LH levels. An eight-week simulating mountain climbing training protocol may be beneficial in maintaining normal endocrine function during and after high altitude mountain expedition.

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