Effect of different levels normobaric hypoxia on the concentration of selected biochemical variables during single resistance exercise in men and women

Summary

The concept of Intermittent Hypoxic Training (IHT) is a well-studied training method involving exposure to hypoxia during a normobaric training session. The effectiveness of this method is based on the premise that training stress is compounded by the hypoxic environment, leading to greater adaptive changes. IHT training can be effectively implemented in a variety of sports from typical speed to endurance disciplines, depending on the training stimulus set.

The effectiveness of intermittent hypoxia training and the growing evidence of the positive effects of occlusion training have led researchers to become interested in the topic of using systemic hypoxia during resistance exercise. Currently, there are not many papers examining the effectiveness of resistance training in a hypoxic environment. There are also few papers in the literature that describe the adaptive mechanisms that may favor training in normobaric hypoxia over conventional resistance training in normoxia. There is a lack of methodological recommendations on training programming, recommended loads, rest intervals, and there is very little work that focuses on the intensity of the set stimulus in the form of hypoxia intensity. Only the last few months have brought the first information on the hormonal and metabolic response of women to resistance exercise in a hypoxic environment.

The aim of the present study is to analyze changes in testosterone (T), cortisol (C), growth hormone (GH) and selected metabolic markers such as lactate (LA), creatin kinase (CK), lactate dehydrogenase (LDH) and uric acid (UA) after resistance exercise in normoxia and normobaric hypoxia at different intensities of 3000 m (FiO2=14.4%), 4000 m (FiO_2=12.7%) and 5000 m (FiO_2=11.2%) in physically active men and women. A novel aspect of the study is the use of three different simulated altitudes (3000 m, 4000 m and 5000 m) to determine the effect of the strength of the hypoxic stimulus on the metabolic and hormonal response to resistance exercise. This may help to provide methodological guidelines for the implementation of resistance training under hypoxic conditions in men and women.

Eight men (age 24.1 ±0.6 years; body height 177.0 ±4.4 cm; body weight 79.4 ±9.7 kg) and eight women (age 24.5 ±0.9 years; body height 164.3 ±2.2 cm; body weight 62.8 ±8.8 kg) participated in the study. The study participants had recreationally performed resistance training for a minimum of 2 years before the start of the study and had not been exposed to hypoxia for the past 6 months. The women declared that they were menstruating regularly and were not using hormonal contraception. The study work lasted 4 weeks and included 5 visits by the participants to the laboratory. The first visit included the determination of 1 RM under normoxia. After 3 days, the subjects performed the first test series. The study was conducted using a blinded crossover method. The conditions under which they performed the resistance exercise were randomized. Week after week, every 7 days, 4 series were completed under normoxia and normobaric hypoxia conditions at 3000 m (FiO2=14.4%), 4000 m (FiO2=12.7%) and 5000 m (FiO2=11.2%). Blood was collected after 15 min of rest in normoxia or hypoxia, immediately after completion of the last series of squats, and 60 min after the completed exercise. The resistance exercise testing protocol included 10 series of 12 repetitions with a load of 70% 1 RM for the barbell squat. The interval between series was 3 min. If the subjects were unable to complete the set number of repetitions they stopped the series and, after a recovery break, continued the exercise to the 10 series completed.

The results of the study showed that in men, the total number of repetitions performed during resistance exercise in hypoxia at an altitude of 5000 m was lower (at the limit of the accepted level of significance, $p<0.09$) than in normoxia. In the women's group, no significant differences were noted in the number of repetitions performed, regardless of the conditions of exercise execution. There was a statistically significant increase in LA concentration under resistance exercise in normoxia and for each trial in hypoxia in men and women. The increase in LA concentration was significantly lower at 5000 m than at 3000 m ($p<0.01$) and 4000 m ($p<0.05$) in the male group. The increase in LA concentration was significantly higher at 3000 m ($p<0.001$), 4000 m ($p<0.01$) and 5000 m ($p<0.001$) than in normoxia in the women's group. Moreover, in the men's group, the increase in CK activity immediately after exercise and 1h after exercise was significantly lower at 5000m than at 3000m. The women's group showed that the increase in CK activity 1h after exercise was significantly greater ($p<0.05$) in hypoxia at 3000 m and 4000 m than in normoxia, while the difference between LDH activity at rest and 1h after exercise was significantly greater ($p<0.05$) at 5000 m than in normoxia and at 3000m.

In the men's group, there was a significant increase in T after resistance exercise compared to rest in normoxia and at 3000 m, but altitude did not differentiate these changes. C concentration increased significantly immediately after exercise at 4000 ($p<0.001$) and 5000 m ($p<0.01$) and significantly decreased 1 h after exercise below baseline at 4000 m ($p<0.01$), these changes were differentiated by altitude, but only at 4000 m. Also at 4000m, there was a significant decrease in T/C ratio and these changes differentiated hypoxia conditions. A significant increase in GH concentration in the men's group immediately after resistance exercise was recorded in each of the trials, but altitude did not differentiate these changes.

In the women's group, a significant increase in T was observed immediately after the resistance exercise and 1 hr after in the 4000m and 5000m trials, altitude differentiated these changes. C concentration increased significantly immediately after exercise in the normoxia trial ($p<0.01$) and at 4000 ($p<0.07$) and significantly decreased 1 h after exercise below baseline in the normoxia trial only ($p<0.01$). Significant increases in GH concentrations in the women's group immediately after resistance exercise were recorded in each of the trials. In the 5000m trial, the increase in concentration immediately after exercise was significantly higher than at 3000m.

In conclusion, the results of our own work showed that high-intensity hypoxia (5,000m) has a limiting effect on muscular performance during resistance exercise in men. In contrast, in women, the hypoxic environment does not limit muscular performance, regardless of the degree of hypoxia intensity (3000 - 5000 m), which is probably related to the lower external load relative to body weight observed in women relative to men.

In men, high-intensity resistance exercise performed under normoxia significantly increases T and GH concentrations. Hypoxia (3,000 - 4,000 m) affects a stronger C response and a suppressed T response in men, in addition, it slightly affects higher GH output. Further increases in altitude do not potentiate the changes due to a reduction in muscular performance and affect a reduced metabolic response. Moderate-intensity hypoxia (3000 - 4000 m) during high-intensity resistance exercise can enhance the hormonal and metabolic response to the training stimuli while maintaining the resistance performance presented in normoxia.

In women, high-intensity resistance exercise performed under normoxia significantly affects C and GH increases. High-intensity hypoxia (4,000 - 5,000 m) affects a stronger T and GH response compared to moderate-intensity hypoxia (3,000 m), while causing little change in C concentration. In addition, resistance exercise in hypoxia (3000 - 5000 m) affects a significantly greater increase in LA, higher CK activity (3000 - 4000 m) and LDH (5000 m) compared to normoxia. The use of high-intensity hypoxia during resistance exercise in women seems beneficial to intensify the training stimuli and enhance beneficial adaptive changes due to the stimulation of anabolic processes in the body.