Increase in plasma growth hormone after resistance training under hypoxic conditions

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Abstract

The purpose of this study was to clarify whether plasma concentrations of GH and lactate (La) are concurrently elevated by resistance training under 15.4 % of hypoxic conditions. Six athletes (age, 21.6 ± 1.0 y; height, 175.6 ± 5.6 cm; weight, 70.4 ± 16.3 kg; means ± SD) provided written, informed consent to participate in this study. Seated participants ($n = 6$) performed 3 sets of 10 repetitions each of bilateral knee extensions at an intensity of 60 % 1Repetition Maximum (RM) at 2 min intervals using an isotonic leg extension machine under normoxic and hypoxic conditions. Plasma concentrations of growth hormone (GH) lactate (La) were measured before and after the training. Concentrations of GH significantly increased at 0 min before and 0 min after exercise under hypoxic conditions ($p < 0.05$ Wilcoxon signed rank test). The concentration of La tended to be higher after exercise under hypoxic, than normoxic conditions but the difference was not significant. The overall rating of perceived exertion (RPE) did not significantly differ between normoxic and hypoxic conditions. Resistance training under 15.4 % hypoxic conditions have stimulated the secretion of GH than normoxic conditions.

Key words

hypoxic conditions, resistance training, growth hormone, lactate, rating of perceived exertion

1. Introduction

High altitude training is generally thought to increase erythropoietin and maximal O_2 uptake (VO_2 max) and is thus useful for improving performance. Levine et al. (1991) advanced the concept of "living high, training low" in 1991. More recently, an "altitude house" has been developed to study the "living high, training low" concept at sea level. A normobaric hypoxic atmosphere was created in the altitude house by increasing the nitrogen concentration in inspired air (Rusko, 1996). Rusko proposed that the living high, training low concept using the altitude house would be an optimal means of enhancing sea-level performance in elite endurance athletes and many investigations have been conducted to address this notion.

On the other hand, more recently, there are some studies that prove the benefit of resistance training under hypoxic conditions. Kurobe et al. (2014) reported that a training of arm extension consisted of three sets of 10 repetitions at a mean intensity of 10 Repetition Maximum (RM) thrice weekly for 8 weeks caused muscular hypertrophy. Kon et al. (2012) reported that a resistance training with bench-press and leg press consisted of 5 sets of 14 repetitions at 50 % Maximum voluntary contraction (MVC) had marked increased plasma growth hormone. Takarada et al. (2000; 2002; 2004) reported that levels of plasma growth hormone (GH) rapidly increase after low-intensity resistance exercise with vascular occlusion and that this leads to muscle hypertrophy. However, these studies have been done using hypoxia 12-13 % or ischemia, which is much lower than the actual altitude level in high altitude training. It is necessary to investigate the use of lower hypoxia similar to the actual training environment.

The effects of resistance training upon the knee extensors under 15.4 % hypoxic conditions (correspond to 2,500 m above sea level) were investigated to determine whether plasma concentrations of GH and lactate (La) are concurrently elevated under 15.4 % of hypoxic conditions.

2. Methods

2.1 Subjects

Six athletes (age, 21.6 ± 1.0 y; height, 175.6 ± 5.6 cm; weight, 70.4 ± 16.3 kg; body fat, 15.2 ± 6.0 % means ± SD) provided written, informed consent to participate in this study. The exercise load was determined relative to the maximal weight that could be lifted throughout the whole range of movement (one repetition maximum, 1 RM). The Ethical Committee for Human Experiments at Mie University approved the study.

2.2 Hypoxic room

A room was covered with an assembled transparent airtight vinyl tent (width × depth × height, 2,900 × 2,000 × 2,200 mm^3). Oxygen and carbon dioxide levels in the room during the training were monitored. Membrane separation enabled hypoxic conditions to be controlled at 15.4 % O_2.

Training regimen: The participants rested in a hypoxic room for 5 min, warmed up for 10 min on an aerobike (COMBI, POWERMAX-VII; 60 W, 60 rpm) and then rested for a further 50 min before performing bilateral knee extensions from 0°

to 90° (0° at full extension) in a seated position using an isotonic leg extension machine (DANTOS®). The resistance training session consisted of three sets of 10 repetitions at a mean intensity of 60 % of 1 RM, at intervals of 2 min between sets. The same individuals repeated the exercise under normoxic conditions as a control.

2.3 Blood sampling and analysis

Venous blood samples were obtained from a superficial arm vein from slightly reclined, seated subjects. Resting blood samples were obtained after 5 and 50 min of equilibration in the hypoxic room before the training sessions started. After the exercise sessions, blood samples were obtained at immediately (0 min) and at 30 min after exercise. All blood samples were processed and stored at -20 °C until analysis. The plasma concentration of La was determined spectrophotometrically using a lactate dehydrogenase-coupled enzyme system, and plasma GH concentrations were measured using a radioimmunoassay (Bando et al., 1992).

2.4 Rating of perceived exertion (RPE)

The Borg 6-20 rating of perceived exertion (RPE) scale (Borg, 1982) assesses sensations of exertion relative to physiological markers that increase with increments in exercise intensity. The RPE was determined at the rest phase, 0 min before, 0 min after, and 30 min after training in response to the question, "How do you feel right now?" The subjects rated their RPE according to a printed copy of the Borg scale. This self-reported scale is graded from 6 to 20 and uses descriptive cues for each category of exertion within the scale ranging from "very, very light" to "very, very heavy".

Statistical analysis: Unless otherwise stated, variables are described as means ± standard error (SE). A Wilcoxon signed ranks test was used to compare differences between variables under normoxic and hypoxic conditions. For all analyses, $p < 0.05$ was regarded as significant.

3. Result

Plasma concentration of lactate (La). Figure 1 shows the plasma concentration of La before and after training. The average La values at the rest phase, 0 min before, 0 min after and 30 min after resistance training under normoxic conditions were 1.8 (± 0.2), 1.8 (± 0.3), 5.1 (± 1.0) and 1.9 (± 0.3) mmol/l respectively. On the other hand, these values under hypoxic conditions were 1.4 (± 0.1), 2.1 (± 0.3), 5.9 (± 1.4) and 2.6 (± 0.4) mmol/l respectively. The average La at all times did not significantly differ between normoxic and hypoxic conditions.

The La value of the resting phase was considered as 100 % and it was compared with the values at all other phases (Figure 2). The La at 0 min before, 0 min after and 30 min after resistance training under normoxic conditions were 99.5
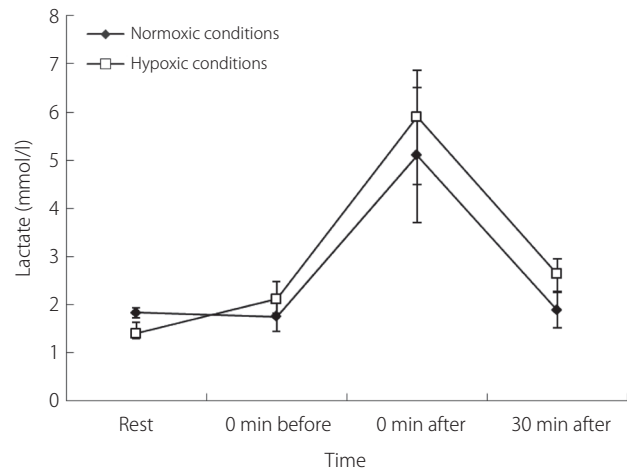

Figure 1: Changes in plasma lactate concentrations before and after exercise
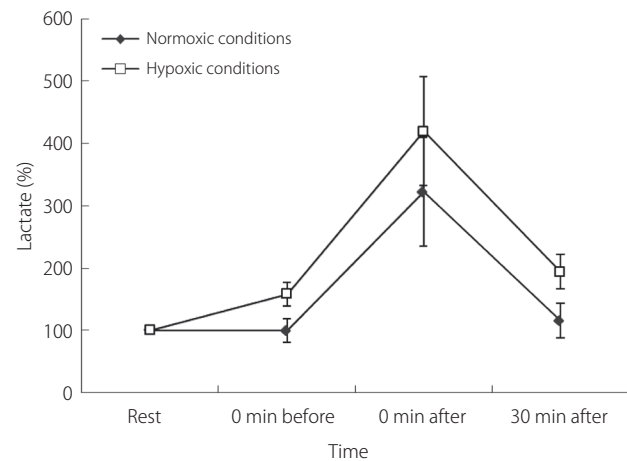Note: Data are means ±SE.

Figure 2: Changes in plasma concentration of lactate considering value at rest as 100%
Note: Data are means ±SE.

(± 18.7), 321.9 (± 87.0) and 115.4 (± 27.9) % respectively. On the other hand, these values under hypoxic conditions were 158.2 (± 29.6), 419.5 (± 82.5), and 193.8 (± 32.3) % respectively. Overall average La values did not significantly differ between normoxic and hypoxic conditions. However, the La values at 0 min before and at 30 min after resistance training under hypoxic conditions were 58.8 % and 78.4 % higher than the resting value under normoxic conditions. The average La value tended to be higher after exercise under hypoxic than normoxic conditions.

3.1 Plasma concentration of GH

The GH values of the rest phase varied among athletes and within the same athlete, and considerably differed between hypoxic and normoxic conditions. Therefore the GH value
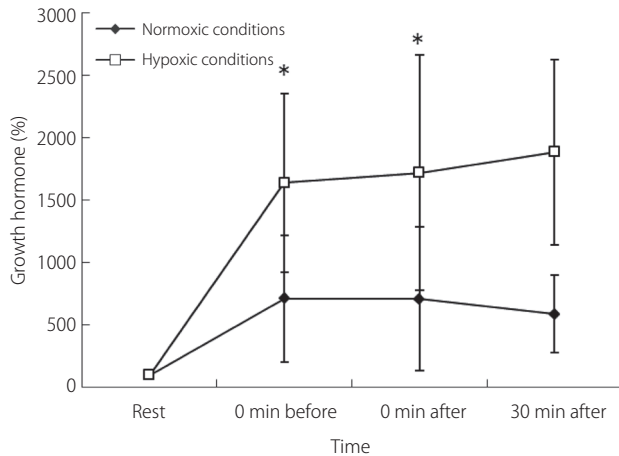
Figure 3: Changes in plasma concentration of growth hormone considering value at rest as 100 %

Notes: Data are means (SE).
Significant differences between normoxic and hypoxic conditions.
* *p* < 0.05, Wilcoxon signed ranks test.

Figure 4: Changes in rating of perceived exertion (RPE)
Note: Data are means ±SE.

of the rest phase was considered as 100 % and compared with the values at all phases. Figure 3 shows that the average plasma concentration of GH before (0 min), and at 0 and 30 min after exercise under normoxic conditions were 714.7 (± 507.3), 708.3 (± 575.2) and 590.1 (± 307.6) % respectively of the value at rest. On the other hand, these values after exercise under hypoxic conditions were 1,640.4 (± 713.6), 1,721.1 (± 942.6) and 1,886.4 (± 740.5) % respectively. The GH value at 0 min before exercise under normoxic conditions was 925.7 % of the rate under hypoxic conditions (significantly different, *p* < 0.05). The GH value at 0 min after exercise under normoxic conditions was 1,012.8 % of that under hypoxic conditions (significantly different, *p* < 0.05). The other GH values did not significantly differ between normoxic and hypoxic conditions, but tended to be higher at 30 min after exercise under hypoxic, than normoxic conditions.

3.2 RPE

Figure 4 shows RPE measured before and after exercise. The RPE of the rest phase, 0 min before and at 0 and 30 min after training under normoxic conditions were 9 (± 0), 9.7 (± 0.3), 12.7 (± 0.6) and 9.5 (± 0.8) respectively. These values under hypoxic conditions were 8.8 (± 0.2), 8.7 (± 0.52), 12.5 (± 0.3) and 9.3 (± 0.3) respectively. The RPE values did not significantly differ between normoxic and hypoxic conditions.

4. Discussion

This present study shows that resistance training under 15.4 % of hypoxic conditions causes an increase in plasma GH and La values. The elevated La concentration was presumably promoted by hypoxia, which causes more anaerobic metabolism. An acidic intramuscular environment induced by
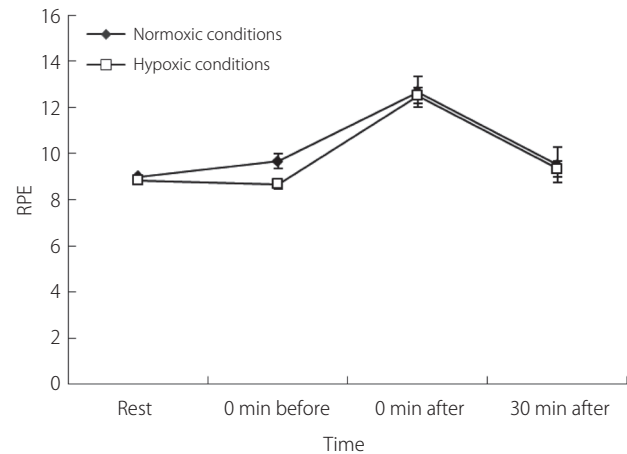
an increased La concentration stimulates sympathetic nerve activity through the chemoreceptive reflex mediated by intramuscular metaboreceptors and group III and IV afferent fibers (Victor & Seals, 1989). The same chemoreception also plays an important role in the regulation of hypophyseal GH secretion (Gosselink et al., 1998). A similar mechanism might have operated in the present study under hypoxic conditions, because the GH and La concentrations changed in phase.

Several lines of evidence show that GH and IGF-I play crucial roles in the growth, development, and maintenance of skeletal muscle. In particular, transgenic animals that over-express the mRNAs for GH (Palmiter et al., 1983) and IGF-I (Mathews et al., 1988; Renganathan, et al., 1998) have highly developed muscularity and a suppressed age-related decline in muscular size and function, respectively. Circulating GH stimulates the synthesis and secretion of IGF-I within muscle, which then acts on the muscle itself to promote growth (DeVol et al., 1990; Isgaard et al., 1989; Turner et al., 1988). Although whether or not the administration of exogenous GH and IGF-I stimulates muscular growth in adult humans (Burdet et al., 1997; Butterfield et al., 1997; Taaffe et al., 1994; Vittone et al., 1997; Yarasheski et al., 1992; 1995) has been controversial, combinations of GH and exercise evoke interactive, positive effects in potentiating muscular hypertrophy in both humans and rats (Grindeland et al., 1994; Linderman et al., 1994; Thompson et al., 1998).

As Kurobe et al. (2014) found a training of arm extension under 12.7 % of hypoxic conditions resulted in muscular growth, it can be proved that circulating GH also stimulates secretion of muscular hypertrophy. In this present study, although 15.4 % level of oxygen were used differently from 12 to 13 % used in the previous study, the results could imply that resistance training under hypoxic conditions induces the intramuscular state required for muscular hypertrophy. The results also suggest that such exercise under 15.4 %

level of hypoxic conditions is useful for resistance exercise, as well as aerobic training. Our group (Nishimura et al., 2010) reported that a group trained under 16 % hypoxic conditions proceeded at an exercise intensity of 70 % of 1 repetition maximum (RM), and comprised four sets of 10 repetitions of elbow extension and flexion twice weekly for 6wk significantly increased muscle cross-sectional area greater than a different group trained under normoxic conditions ($p < 0.05$). However, a relationship between muscular hypertrophy and GH was not considered in their study. The result of this study indirectly indicates muscular hypertrophy caused by a resistance training under 16 % hypoxic conditions accompanied by increase in plasma GH.

Resistance exercise under vascular occlusion (VO) invokes more GH than the resistance training performed in the present study (Takarada et al., 2000). If a specific muscle in the extremities needs to be trained, then VO is useful. However, VO cannot be adapted to trunk and systematic training because a tourniquet is required. The regimen described in the present study can include trunk and systematic exercises and result in well-balanced musculature. Overall RPE in the present study did not significantly differ between normoxic and hypoxic conditions, so fatigue did not seem to differ between the two conditions. To our knowledge, the RPE of VO has not been described, but we assume that it would be higher than in the present study because of the effect of the tourniquet.

In this present study, the degree of the increase of GH and La might be small because the level of hypoxic level oxygen was 15.4 % and further also the load of exercise was only 60 % of 1 RM. However, because a resistance training under 15.4 % hypoxic conditions have stimulated the secretion of GH in this study, the result supports the findings of our previous report (Nishimura et at., 2010) from the aspect of growth hormone. Further study will be necessary to identify a desirable method of resistance training under hypoxic conditions by investigating an optimum combination of a level of oxygen concentration, a load, a time for rest, and the number of sets.

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