A single set of low intensity resistance exercise immediately following high intensity resistance exercise stimulates growth hormone secretion in men

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Aim. The purpose of the present study was to examine the effects of an additional set immediately following high intensity resistance exercise on growth hormone (GH) response. Methods. Subjects (n=8) performed 4 resistance exercise protocols (bilateral knee extension exercise) on separate days. The protocols were categorized into 2 types of protocol, namely “Strength-up type (S-type)” and “Combination type (Combi-type)”. The S-type was resistance exercise which consisted of 5 sets at 90% of 1 repetition maximum (RM) with 3-min rest periods between sets, whereas the Combi-type is a training protocol which adds an additional set (either 50% of 1 RM [C50-type], 70% of 1 RM [C70-type] or 90% of 1 RM [C90-type]) to the S-type. Serum GH concentration and blood lactate concentration were determined pre-exercise and at 0-60 min postexercise. Relative changes in thigh girth and maximal unilateral isometric strength were determined pre-exercise and immediately postexercise. Results. The increasing values of GH concentration (ΔGH) in the S-type was the lowest of all protocols. On the other hand, ΔGH in the C50-type showed a significantly (p<0.05) higher increase than in the S-type and C90-type, and a relatively higher increase than in the C70-type. Conclusion. These results suggest that a high intensity, low volume training protocol to induce neural adaptation resulted in little GH response, but GH secretion was increased by performing a single set of low intensity resistance exercise at the end of a series of high intensity resistance sets.

Key words: Resistance exercise - Strength-up type - Bulk-up type - Growth hormone.

Resistance exercise has various training regimens which were originally designed by strength coaches, athletes or sports scientists. Whereas all resistance exercise regimens produce an increase in strength and muscle hypertrophy to a greater or lesser extent, these training regimens have been generally categorized into 2 typical types with different objectives, namely “Strength-up type (S-type)” and “Bulk-up type (B-type)”.1,2 The S-type is used by weight lifters and consists of high intensity exercise (above 90% of 1 repetition maximum: 1 RM) with low volume and long rest periods between sets. This type is utilized to increase muscle strength and power. On the other hand, the B-type is used by bodybuilders and consists of moderate intensity exercise (about 60% to 75% of 1 RM) with higher volume and shorter rest periods between sets. This type is utilized to induce muscle hypertrophy.3,4 Although the S-type is useful in order to increase muscle strength and power, remarkable muscle hypertrophy is not observed. This result is due to multiple factors, and one of the them is the role of endocrine activity, such as growth hormone (GH) and testosterone. These hormone are called “anabolic hormone” and affect protein synthesis on activated muscle fibers.5,6

A number of studies have described endogenous acute
strength and power, however, the characteristics of the Combi-type have not been investigated. Additionally, the training method of the additional set which provides the greatest responses in serum GH concentration has not been fully understood. Therefore, the purpose of the present study was to examine the effects of an additional set immediately following the S-type on GH response with special reference to the difference in the exercise intensity of the additional set.

Materials and methods

Subjects

Eight active male subjects aged 20–23 years participated in the study. Their physical characteristics were height, 1.75±0.01 (SE) m, and body mass, 71.5±2.0 kg. All the subjects had recreational experience with resistance training and were not taking supplements (e.g., amino acid, creatine), anabolic steroids or other drugs that were expected to affect growth hormone secretion before the study. In addition, all of them were asked to maintain their normal living activities and daily normal diet during the experimental period. They were previously informed about the experimental procedure to be utilized as well as the purpose of the study, and their written informed consent was obtained.

Experimental design and exercise protocol

The exercise used for acute resistance exercise was bilateral knee extension in a seated position using an isotonic leg extension machine. The range of the movement was from 90° to 180° (defined as 180° at full extension). To maintain the upper body position constantly, the subjects crossed their arms in front of their chest throughout the exercise. A minimum of 1 week was spent for experimental protocol familiarization and descriptive testing.

All the subjects performed 4 resistance exercise protocols in random order. They were not allowed to consume caffeine and alcohol and to participate in strenuous activity during the 72 hours before testing. Each exercise protocol was separated by more than 7 days. The experimental exercise protocols are shown in figure 1. The S-type was resistance exercise which consisted of 5 sets at 90% of 1 RM with 3-min rest periods between sets. The Combi-type was characterized by an additional set following the S-type. Thirty-

![Diagram of exercise protocols](image-url)
sec rest periods were set up between the S-type and the additional set. The load used in the additional set was either 50% of 1 RM (C50-type), 70% of 1 RM (C70-type) or 90% of 1 RM (C90-type). The exercise performed in all sets of all protocols was repeated until exhaustion at a frequency of 30 extensions per minute.

**Measurement**

Venous blood samples were obtained from an indwelling cannula in antecubital vein (5 ml for each point of measurement). Blood samples were obtained pre-exercise and at 0-60 min after each exercise protocol. The samples for GH measurement were centrifuged for 10 min at 3000 rpm to obtain serum and were preserved at -80°C until analysis. From the obtained blood samples, serum GH concentration (pre-exercise, 5, 15, 30 and 60 min postexercise) and blood lactate (LA) concentration (pre-exercise, every 1-5 min, 7, 10, 12, 15, 30 and 60 min postexercise) were measured. The increasing values of GH and LA concentration between pre- and postexercise were defined as ΔGH and ΔLA, respectively. GH concentration was measured by radioimmunoassay, and LA concentration was measured using an automatic lactate analyzer (YSI1500 sport, Yellow Springs Instruments, OH, USA). All blood sampling was conducted at the same time of day to reduce the effects of any diurnal variations on the hormonal concentration. In addition, during the 12 hours prior to testing, subjects were not allowed to consume any dietary in order to avoid the influence of protein and/or amino acid uptake on secretion of GH.

The thigh girth of the right leg was measured pre-exercise and immediately postexercise. Measurement of thigh girth was performed twice at 15 cm above the patella, and the average value of each was adopted. Relative change in thigh girth was defined as %Girth.

Maximal unilateral isometric strength (ISOMax) was measured at a knee angle of 90° in a seated position pre-exercise and immediately postexercise. A strain gauge was connected from the lever arm to a stationary support and the output from the strain gauge was stored in a computer (NEC, Tokyo, Japan). Two testing contractions were recorded pre-exercise and immediately postexercise, and the average value of each was adopted. Relative change in ISOMax (the decreasing rate) was defined as %ISOMax.

To determine the load used in exercise sessions, 1 RM was measured before each experimental exercise.

**Statistical analysis**

Data are expressed as means±SE. Statistical significance of the data among each exercise protocol was assessed by a one-way analysis of variance (ANOVA) and Scheffé's posthoc comparison. Pearson product moment coefficient of correlation was calculated to determine the relationships among each parameter. Statistical significance level was set at p<0.05.

**Results**

No significant change was observed in height, body mass and muscle strength (ISOMax, 1 RM) over the course of the experiment and no significant difference was shown in GH concentration and LA concentration pre-exercise among the each exercise protocol. Table I shows the number of repetitions for each set, and work volume and work rate of the additional
set in the Combi-type. The number of repetitions for 1st-5th set using the same relative load was almost constant (range from 4.8 to 5.3). The number of repetitions and work volume of the additional set (6th set) in the Combi-type showed significantly different values in the C50-type (24.4±1.8, 5399±456 J), the C70-type (13.1±0.9, 4200±341 J) and the C90-type (3.6±0.4, 1451±116 J). On the other hand, the work rate showed significantly different values in the C90-type (228±13 W), the C70-type (182±9 W) and the C50-type (132±7 W).

Figure 2 shows ΔGH, ΔLA, %Girth and %ISOmax in each exercise protocol. These values in C50-type were consistently the highest, subsequently those in C70-type, C90-type and S-type: ΔGH, ΔLA, %Girth and %ISOmax were 5.9±0.9 ng/ml, 4.3±0.3 mmol/l, 4.8±0.4% and -18.1±3.0%, respectively, in C50-type; 3.9±0.9 ng/ml, 3.8±0.3 mmol/l, 3.1±0.2% and -14.4±2.7% in C70-type; 1.20±0.6 ng/ml, 1.7±0.4 mmol/l, 2.0±0.4% and -11.6±4.1% in C90-type; and 1.0±0.2 ng/ml, 1.6±0.3 mmol, 1.2±0.2% and -6.3±3.0% in S-type.

Figure 3 shows the relationships of ΔLA and %Girth with ΔGH in the 4 resistance exercise protocols. Significant correlations were found between ΔGH and both ΔLA (left; r=0.75, p<0.05) and %Girth (right; r=0.64, p<0.05) when the results of 4 exercises were combined.

Figure 4 shows the relationships of the number of repetitions, work volume and work rate of the additional set in the Combi-type with ΔGH. Significant correlations were found between ΔGH and both the number of repetitions (left; r=0.70, p<0.05) and the work volume (center; r=0.80 p<0.05) when the results of 3 exercises were combined, however, there was no significant correlation between ΔGH and the work rate (right; r=−0.33, ns).
Discussion and conclusions

The major finding in the present study was that an additional low intensity set of exercise (single set at 50% of 1 RM) immediately following a series of high intensity exercise (5 sets at 90% of 1 RM) significantly increases GH secretion. \( \Delta \text{GH} \) in the S-type was the lowest value of all exer-
Exercise protocols, and GH secretion in this type was not stimulated. This result is consistent with some earlier reports that the training protocol using high intensity, low volume and long rest periods between sets induced little GH increase.8, 9, 13

As shown in Figure 2, ΔGH in the C50-type showed a significantly higher increase than in the S-type and C90-type, and a relatively higher increase than in the C70-type. About 6 times (1.0 ng/ml vs. 5.9 ng/ml) difference was also observed between the value of S-type and that of C50-type. Moreover, ΔGH in the C50-type was not as high as that in the Bulk-up type protocol (multipoundage system; 9 sets at 80-40% of 1 RM, 30-sec or 3-min rest between the sets), but the difference in ΔGH between protocols (about 1.7 times, 5.9 ng/ml vs. 10.0 ng/ml) was relatively minor compared to that of the total work volume (about 2.0 times, 14.9 KJ vs. 29.4 KJ, unpublished data). Contrary to these findings, Vanhelder et al.7 have shown that GH increase from a single set of leg press exercise at low intensity is smaller than that at moderate intensity. As main reason for this different result, it is speculated that the work volume for the additional set was not matched in the present study, whereas the work volume for each exercise protocol was controlled in an investigation by Vanhelder et al.

A decrease in blood pH as result of lactate production has been suggested as one mechanism by which exercise may stimulate GH secretion.8, 13 Although the interpretation of whole blood lactate concentration must be done cautiously because of different values between blood and muscle, it is known that blood lactate concentration can reflect the extent of protons generated in working muscle to some extent. Additionally, it has been shown that a rapid increase in working muscle size after exercise is derived from increased water content, and this phenomenon is indeed fluid shifted from the vascular space to the surrounding muscle tissue. Moreover, this results from changing osmotic gradients because of accumulating metabolites in the working muscle.14-16 Thus, it seems that when metabolite changes in the working muscle are greater, increases in muscle size are also greater. Based on these findings, ΔLA and %Girth can become markers of the extent of protons generated in a working muscle. In the present study, both ΔLA and %Girth in C50-type is higher than in other exercise protocols. (Figure 2). Furthermore, significant positive correlations were observed between ΔGH and both ΔLA (r=0.75, p<0.05) and %Girth (r=0.64, p<0.05) when the results of 4 exercises were combined (Figure 3). Thus, these results support the earlier finding that greater metabolite changes in a working muscle resulted in a greater GH response.17, 18 As for this point, it is hypothesized that metabolite accumulation and subsequent acidification within the muscle stimulate metaboreceptors,19 which may then lead to activation of the hypothalamic pituitary axis by afferent signals and GH secretion.20

As shown in Figure 4, significant correlations were found between ΔGH and both the number of repetitions (r=0.70, p<0.05) and the work volume (r=0.80, p<0.05) of the additional set in the Combi-type. This result suggests that increases in the work volume of the additional set is an important factor in enhancing GH secretion. On the other hand, it is possible that increases in work volume of the additional set using low resistance suppress the training effect for the S-type (e.g., neural adaptation, gain in muscle strength). In fact, several previous studies indicated that gains in muscle strength to resistance training is inhibited when muscular endurance training is performed concurrently.21-24 Thus, further studies are needed to clarify the influence of performing an additional set on training effect for the S-type.

The increase of GH secretion theoretically has an effect in enhancing protein synthesis during the subsequent phase of recovery.11 This is also supported by many reports reviewed by Miers and Barrett.25 In addition, some researchers have speculated that elevation of GH concentration has affected the secretion of local growth factor such as insulin-like growth factor-1 (IGF-1) from liver26 and muscle itself,27, 28 which stimulates protein synthesis on activated muscle.27, 28 It is therefore possible that muscle protein synthesis is facilitated by performing a single set of low intensity exercise immediately following a series of high intensity resistance exercise. However, caution must be demanded, because the actual effect of exercise-induced GH increase on a stimulation of contractile proteins is unknown. In future, it is essential to examine this point focusing on muscle adaptation to prolonged resistance training.

In the present study, GH responses to acute resistance exercises were examined. However, the actions of other hormones such as testosterone and cortisol are reported to also play an important role in regulating protein synthesis.9 Unfortunately, since we did
not examine the changes of concentrations of these hormones, further study should be performed to clarify the characteristics of the C50-type.

In summary, a high intensity, low volume training protocol to induce neural adaptation resulted in little GH response, but GH secretion was increased by performing a single set of low intensity exercise at the end of a series of high intensity resistance sets. To define the usefulness of the C50-type, future studies should examine several different points of view, such as IGF-1 response, neural and muscle adaptation to prolonged training, and a way of adopting these into a training schedule.

References