1. Introduction

Regimens in resistance exercise training have been generally categorized into two major types according to objectives: "strength-type" and "hypertrophy-type". The former consists of high-intensity exercises [1-8 repetition maximum (RM)] with long rest periods between sets (approximately 2-5 min), and is used to increase maximal muscular strength. The latter consists of moderate-intensity exercises (8-15 RM) with short rest periods between sets (approximately 0.5-2 min), and has been thought to be effective in gaining muscle size and muscular endurance [Kraemer et al. (1987); Fleck & Kraemer (1997); Choi et al. (1998)].

The mechanism for the specific training effects of the "strength-type" and "hypertrophy-type" regimens involves many factors; i.e., mechanical, metabolic, neural and endocrine factors. Among endocrine factors, actions of anabolic hormones such as growth hormone (GH) and testosterone (TES) have been clearly shown to stimulate protein synthesis and to promote muscle hypertrophy [Florini (1987)]. From this viewpoint, a number of studies have investigated acute anabolic hormone responses in males and females [Kraemer et al. (1990, 1993)], and young and elderly subjects [Häkkinen & Pakarinen (1995)]. These studies show that many types of resistance exercise appear to stimulate secretions of anabolic hormones, but the responses of hormones, especially...
GH, are relatively small after high-intensity and low-repetition exercises such as those used in the "strength-type" regimen [Kraemer et al. (1990, 1993); Häkkinen & Pakarinen (1993); Goto et al. (2003b)]. Because some earlier studies indicate a positive correlation of the magnitude of GH or TES responses with either strength improvement [Häkkinen et al. (2001); Hansen et al. (2001)] or muscle fiber hypertrophy [McCall et al. (1999)], greater training effects can be expected if secretion of these hormones is separately stimulated after a "strength-type" regimen.

We had previously evaluated the GH concentrations after varied exercise regimens, in which a single set of exhaustive exercise at either 90% 1RM, 70% 1RM or 50% 1RM was added after a "strength-type" regimen. Our results indicated that performing an additional set of exercise at 50% of 1RM immediately after a "strength-type" regimen caused a marked increases in blood lactate and serum GH concentrations [Goto et al. (2003a)]. Moreover, we had shown that this type of exercise regimen increased maximal muscular strength and cross sectional area (CSA) more than a conventional "strength-type" regimen in a periodized training period [Goto et al. (in press)].

As mentioned above, the acute and long-term effects of an exercise regimen with combined high- and low-intensity (50% of 1RM) resistance exercises were investigated, and we were curious to know whether a single set of extremely low intensity (below 50% of 1RM) exercise added to the "strength-type" regimen would induce a greater anabolic hormonal response. An extremely low-intensity, high-repetition exercise following a "strength-type" regimen might cause a greater hormonal secretion due to augmentations of the number of repetition and total work volume. However, blood inflow through the artery would not be suppressed by the force exertion at below 20% of maximal isometric strength [Edwards et al. (1972)], and no great changes in metabolic condition could be expected in the working muscle by the added low-intensity exercise. Since it has been suggested that a local accumulation of metabolic subproducts (e.g., lactate, proton) would stimulate secretion of GH through hypothalamic-pituitary axis [Takarada et al. (2000); Stokes et al. (2002)], the effects of additional exercise with extremely low intensity on hormonal secretions might be little.

In the present study, we investigated the effects of a single set of exercise with an intensity ranging from 50% to 20% of 1RM added after a "strength-type" regimen on concentrations of GH and TES, to clarify how the additional set of exercise with an extremely low-intensity enhanced hormonal secretion.

### 2. Methods

#### 2.1. Subjects

Eight healthy male subjects (age: 24.9 ± 0.7 years, height: 175.8 ± 1.2 cm, body mass: 71.3 ± 2.5 kg, % fat: 18.9 ± 0.9 %) participated in this study. The subjects were graduate students and had a minimum resistance training experience for several years. They did not take part in regular training program at the beginning of the present study. They were informed about the experimental procedure to be utilized as well as the purpose of the present study, and their written informed consent was obtained. The study was approved by the Ethics Committee for Human Experiments, Institute of Health and Sport Sciences, University of Tsukuba.

#### 2.2. Experimental design and exercise protocol

Bilateral knee extension with an isotonic machine was used as the resistance exercise. The same equipment used in our previous studies was prepared in the present study. The range of the movement was from 90° to 180° (180° was defined as full extension). Prior to the testing, the subjects participated in a familiarization period consisting of a total of 2 visits; one visit to familiarize with the exercise protocol, and the other to measure 1RM of bilateral knee extension exercise.

All subjects performed 4 regimens of resistance exercise in a random order. The time interval between each exercise was more than 6 days. Figure 1 shows protocols for each type of exercise regimen. The
strength-type (S-type) regimen consisted of five sets at 90% 1RM with 3-min rest periods between sets. This protocol was designed to gain maximal muscular strength. A single set of exercise at 50%, 30% and 20% of 1RM was added following the last set of the S-type regimen with a rest period of 30-s. These regimens were defined as C50-type, C30-type, and C20-type regimens, respectively. In the added set, the subjects were instructed to lift and lower the load at a constant velocity and frequency (approximately 40 times/min). This type of regimen is similar to an S-type regimen, and an additional set of exercise was performed in order to increase anabolic hormone concentrations of blood [Goto et al. (2003a)]. The exercises in every set of every protocol were lasted until the subjects failed to continue the movement. These exercise regimens were based on our previous study using additional sets at 90-50 % of 1RM. The subjects were allowed to drink water ad libitum until the resting blood sample was obtained.

2.3. Measurements of blood sample

Venous blood samples were obtained from the antecubital vein of the subjects in a seated position (10 ml for each point of measurements) before and 15-min after each exercise. This sampling timing was determined based on the observation of our previous study, in which the maximal GH concentration was observed 15-min after the exercise when the blood samples were consecutively obtained until 60-min after similar type of exercise [Goto et al. (2003a)]. Moreover, because many studies have shown that the highest concentrations of serum GH and TES are seen from 0 to 30 min after various types of exercise regimen [Kraemer et al. (1990); Hansen et al. (2001)], the post-exercise concentrations in the present study (15 min after exercise) appeared to be near the peak level. All blood samples were collected at the same time of the day to reduce the effects of any diurnal variations of the hormonal response [Thuma et al. (1995)]. Following the overnight fast, the subjects came to the laboratory at 8:30 – 9:00 a.m., and took a rest for 30 min prior to the first blood collection. The blood samples were centrifuged at 3000 rpm for 10 min to obtain serum, and serum samples were stored at -85°C until analysis. To eliminate variances among the measurements, all the samples were analyzed by the same kits used in our previous study. In addition, as many samples as possible were assayed in the same run. The concentration of serum GH was measured through radioimmunoassay (RIA) using kits from Daiich Radioisotope Lab (Tokyo, Japan). The limit of detection for GH assay was 0.05 ng/ml. The inter-assay coefficient of variation (CV) was 3.6%, and the intra-assay CV was 3.4%. The concentration of total testosterone (TES) was measured through RIA using kits from DPC Corporation (Chiba, Japan). The limit of detection for TES assay was 5.0 ng/dl. The inter-assay CV was 5.3%, and the intra-assay CV was 5.8%. Blood samples from fingertip for measurement of lactate concentration were also obtained before and 5-min after each exercise. Blood lactate concentration was determined using an automatic lactate analyzer (YSI 1500 sport, Yellow Springs Instruments, OH).

Some previous studies have shown that plasma volume acutely decreases following a resistance exercise [Ploutz-Snyder et al. (1995); Raastad et al. (2000)], and this influences the hormone concentrations of blood. However, in the present study, hormone concentrations were presented as non-corrected values due to the fact that tissues were exposed to an absolute molar concentration [Kraemer et al. (1992)].

2.4. Measurements of muscular strength and thigh girth

Maximal isometric strength (MIS) of the unilateral knee extension exercise was measured before and immediately after exercises, to assess muscular fatigue. The subjects sat on a dynamometer (COMBIT, MINATO Instrument, Tokyo, Japan) with keeping the knee angle at 100˚ (180˚ was defined as full extension) and were instructed to exert maximal isometric strength for 3-s. The highest value among 2-3 trials was adopted as the MIS value. Intra-class correlation coefficient (between measurements) was: = 0.84 for measurement of MIS.

The thigh girth of the left leg was also measured before and 3-min after each exercise. Measurement of the thigh girth was performed twice at the midpoint of the thigh (a middle point between the trochanter major and the lateral epicondylus of fibula), and the mean value was adopted as the thigh girth value. Acute exercise-induced changes in the thigh girth indicated the increased water content in the activated...
2.5. Statistical analysis

Data are expressed as means ± SE. Differences among the regimens were assessed using a two-way analysis of variance (ANOVA) with repeated measures and Fisher’s post hoc comparison. Differences for paired data were examined using student’s paired t-test. Selected bivariate relationships were investigated using a Pearson product moment correlation coefficient. P values of less than 0.05 were considered to be statistically significant.

3. Results

3.1. Weight, the number of repetition, work volume, and average power in the additional set

The number of repetitions from 1st to 5th sets in all regimens showed similar values (range from 3 to 8 times), and no significant difference was seen among the regimens. Weight, the number of repetition, work volume, and average power in the additional set (the 6th set) are shown in Table 1. The data were consistent with experimental conditions of the additional set using 50% to 20% of 1RM. The absolute values of the weight were significantly greater in the C50-type regimen than in the C30-type and C20-type regimens, whereas the number of repetitions was significantly larger in the C20-type regimen than in the C50-type and C30-type regimens. Consequently, the work volume (weight × repetition) of the additional set showed a significantly greater value in the C20-type regimen than in the C50-type and C30-type regimens. Average power output (work volume / exercise duration) of the additional set was significantly greater in the C50-type regimen than in the C30-type and C20-type regimens.

3.2. Changes in growth hormone, testosterone and blood lactate

Changes in GH concentration after exercise are shown in Figure 2. The pre-exercise data showed no significant difference in the GH values among the regimens. Serum GH concentration in all the regimens increased after exercise, and significant changes were seen after the C50-type (pre: 1.4 ± 0.9 ng/ml, post: 7.9 ± 3.4 ng/ml) and C30-type regimens (pre: 0.3 ± 0.1 ng/ml, post: 7.2 ± 3.0 ng/ml). Post-exercise GH concentrations were significantly higher in the C50-type and C30-type regimens than in the S-type regimen, but no significant difference was
Changes in TES concentration after exercise are shown in Figure 3. The pre-exercise data showed no significant difference in TES concentrations among the regimens. Serum TES concentration in all the regimens increased after exercise, but the changes were not significant in any types of regimen. In addition, relative changes of TES were not correlated with those of GH (S-type: r=-0.14, p=0.75; C50-type: r=-0.21, p=0.63; C30-type: r=-0.01, p=0.71; C20-type: r=0.01, p=1.00).

Changes in blood lactate concentration after exercises are shown in Figure 4. Again, the pre-exercise data showed no significant difference in the blood lactate concentrations among the regimens. Blood lactate concentration significantly increased after exercise in all the regimens, and post-exercise values were significantly higher in the C50-type, C30-type and C20-type regimens than in the S-type regimen. However, no significant difference was observed among these 3 types of regimen.

### 3.3. Changes in maximal isometric strength and thigh girth

Changes in MIS and thigh girth after exercise are shown in Table 2. MIS significantly decreased after exercise in all the regimens except the S-type regimen, and post-exercise value in the C30-type regimen was significantly lower than that in the S-type regimen. However, no significant difference in MIS was observed among the C50-type, C30-type and C20-type regimens.

<table>
<thead>
<tr>
<th>Maximal isometric strength (Nm)</th>
<th>Pre-exercise</th>
<th>Post-exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-type</td>
<td>287.7 ± 17.6</td>
<td>272.8 ± 16.4</td>
</tr>
<tr>
<td>C50-type</td>
<td>295.5 ± 12.7</td>
<td>249.5 ± 13.7</td>
</tr>
<tr>
<td>C30-type</td>
<td>300.0 ± 16.3</td>
<td>236.8 ± 15.1</td>
</tr>
<tr>
<td>C20-type</td>
<td>296.5 ± 16.2</td>
<td>244.2 ± 17.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Thigh girth (cm)</th>
<th>Pre-exercise</th>
<th>Post-exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-type</td>
<td>52.9 ± 1.4</td>
<td>53.2 ± 1.4</td>
</tr>
<tr>
<td>C50-type</td>
<td>53.0 ± 1.4</td>
<td>53.8 ± 1.4</td>
</tr>
<tr>
<td>C30-type</td>
<td>52.8 ± 1.3</td>
<td>53.6 ± 1.3</td>
</tr>
<tr>
<td>C20-type</td>
<td>53.0 ± 1.3</td>
<td>53.5 ± 1.4</td>
</tr>
</tbody>
</table>

Values are means ± SE. *: p ≤ 0.05, compared to pre-exercise value.

* C30: p ≤ 0.05, compared to corresponding value of the S-type regimen.
and C20-type regimens.

Thigh girth consistently increased after exercise in all the regimens, indicating that fluid was shifted from the vascular space into the activated muscle [Ploutz-Snyder et al. (1995)]. However, the post-exercise data showed no significant difference among the regimens.

4. Discussion

Although many types of resistance exercise appear to stimulate secretions of anabolic hormones (e.g., growth hormone, testosterone), the type of training regimen has been shown to greatly affect the magnitude of hormone responses, especially that of GH [Häkkinen & Pakarinen (1993); McCall et al. (1999)]. According to Kraemer et al. (1990, 1991, 1993), regimens using moderate exercise intensity, moderate repetitions (10RM) and short rest periods between sets (1-min) considerably enhance GH secretion, whereas those using higher intensity, lower repetitions (5RM) and longer rest periods between sets (3-min) do not. Our results showed that the GH response to only the S-type regimen was small (Figure 2), which was consistent with the results of Kraemer et al. (1990).

Although the actual effects of circulating GH on muscular adaptation are poorly understood, McCall et al. (1999) and Häkkinen et al. (2001) have reported that acute changes in GH are positively correlated with changes in the muscle fiber cross sectional area and muscular strength after a prolonged training. Furthermore, Hansen et al. (2001) have recently shown that an increase in elbow flexor strength was greatly enhanced when GH release was stimulated by performing an additional leg press exercise immediately after the arm curl exercise. These studies suggest that exercise-induced increase in blood GH concentration plays, in part, a role in the muscular adaptation to resistance exercise.

The aim of the present study was to investigate the magnitude of GH and TES responses to different exercise regimens, in which a single set of exercise at 50% to 20% of 1RM was added after an S-type regimen. We had previously investigated the GH response to a similar type of exercise regimen, in which the intensity of the additional single set of exhaustive exercise ranged from 90% to 50% of 1RM. In this range of intensity, 50% of 1RM exercise gave rise to maximal GH response [Goto et al. (2003a)]. In addition, a similar type of regimen with an additional set at approximately 50% of 1RM had been shown to increase muscular strength more than the S-type regimen [Goto et al. (in press)]. In the present study, the concentration of GH was significantly increased by adding a set of exercise with a low-intensity ranging 50% to 30% of 1RM to an S-type regimen. This suggested that an additional set of low-intensity, high-repetition exercise was practically important for enhancement of GH secretion, even if the exercise intensity in the additional set was lower than 50% of 1RM. It was also observed that relative changes in serum GH concentration after the C50-type and C30-type regimens were greater than those after the C20-type regimen with larger work volume, although the differences were not significant (Table 1 and Figure 2). The reason for this was unclear, and larger work volume would not be necessarily a crucial factor for the enhancement of GH secretion in this type of exercise regimen. In addition, our previous and present results suggested that an additional set of exercise with approximately 50% of 1RM had a greater effect on the increase of GH concentration.

Post-exercise values of blood lactate and serum GH were not significantly different among the regimens with additional set (Figure 2 and Figure 4). In addition, relative changes in thigh girth and MIS immediately after exercises were similar in these regimens. A rapid increase in working muscle size is primarily caused by increased water content within the muscles because of metabolite accumulation [Ploutz-Snyder et al. (1995)], and this leads to muscular fatigue and concomitant acute decrease in MIS [Häkkinen & Pakarinen (1995)]. Therefore, the present results implied the lack of marked differences in exercise-induced metabolite changes and muscular fatigue among the regimens with an additional set.

TES production is thought to be involved in the anabolic process in both the human and animal muscles [Pearlman & Crepy (1967); Volek et al. (1997)]. It has been shown that TES concentration elevates after resistance exercises with moderate intensity, short rest periods and sufficient exercise duration, even though changes in its concentration are much smaller than those in GH concentration [Kraemer et al. (1990); Häkkinen & Pakarinen (1995)]. However, the magnitude of TES responses after all exercise regimens was small and not significant. Exercises using larger muscle groups (e.g., bench press, deadlift, squat, leg press), and
those with larger work volume might be required to make serum TES level fully elevate.

In conclusion, although meaningful GH increase was not observed after an S-type regimen, the secretion of GH was significantly enhanced by performing an additional set of low intensity, high repetition exercises (50 to 30 % of 1RM) after an S-type regimen. However, secretion of GH would not be induced, when the intensity of the additional exercise was extremely low (below 20% of 1RM). There were several limitations in interpreting the present results. Investigations with the larger number of subjects, and more frequent measurements of hormone concentrations should be performed to establish the effectiveness of the present training regimen with an additional set. In addition, the mechanism of this training regimen to stimulate GH secretion might need further elucidation.

References
Goto, K., Ishii, N., and Takamatsu, K.


Address:
1-1-1 Tennodai, Tsukuba, Ibaraki 305-8574 Japan

Brief Biographical History:
1999-Master’s Program in Health and Physical Education, University of Tsukuba
2001-Doctoral Program in Health and Sport Sciences, University of Tsukuba
2003-Research Fellow of the Japan Society for the Promotion of Science

Main Works:

Membership in Learned Societies:
• American College of Sports Medicine (ACSM)
• National Strength & Conditioning Association (NSCA)
• Japan Society of Physical Education
• The Japanese Society of Physical Fitness and Sports Medicine
• Japan Society of Exercise and Sports Physiology
• Japan Society of Training Science for Exercise and Sport