ORIGINAL ARTICLE

Acute growth hormone response to low-intensity KAATSU resistance exercise: Comparison between arm and leg

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Exercise is a potent stimulus to GH secretion. However it is unclear if exercise-induced GH release differs between different muscle groups, i.e., arm and leg exercise, when performed at equivalent exercise intensity. The purpose of this study was to compare the GH responses to an acute resistance exercise, combined with restriction of muscular venous blood flow (KAATSU), in muscle groups of the arm and leg. Five young male subjects performed two types of exercise tests, arm and leg exercise, on separate days. The intensity of exercise was 20% of 1-RM, which was measured at least 1 week before the experiment. The external restriction pressure during the KAATSU exercise was selected 50% higher than each measured-arm and estimated-leg systolic blood pressure. Venous blood samples were obtained prior to the start of exercise, immediately post exercise, and 15- and 60-min after exercise, and blood lactate (LA), growth hormone (GH), noradrenaline (NA), hematocrit, albumin and Na/K concentrations were measured. Significant elevations were apparent immediately post and 15-min after exercise for LA and at immediately post, 15- and 60-min after exercise for GH in both arm and leg exercise. Significant elevation was also observed after exercise for NA in both arm and leg, but leg exercise resulted in a greater increase in NA than arm at immediately post exercise. Change in plasma volume after exercise was not different between two exercises. These results suggest that GH secretory responses to exercise may be similar between the arm and leg when performed at equivalent exercise intensity and restriction stimulus.

Key words: resistance training, growth hormone, venous blood flow restriction, noradrenaline

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INTRODUCTION

It is well established that secretion of human growth hormone (GH) is stimulated by physical exercise and that exercise-induced increases in circulating GH might mediate some of the anabolic adaptations induced by exercise, such as muscle hypertrophy, bone mineralization, and local angiogenesis [Cuneo et al., 1991; Kelly et al., 1990]. Since exercise-induced GH secretion is, however, related to exercise intensity in a linear dose-response [Pritzlaff et al., 1999; Schmidt et al., 2004], it would seem likely that there would be a greater GH response after higher intensity physical exercise. In line with this observation, low intensity (i.e., regular life-style physical activity, 10-20% exercise intensity) exercise rarely results in increased serum GH concentrations [Felsing et al., 1992]. However, low-intensity (~20% exercise intensity) exercise, when combined with restriction of venous blood flow from the working muscle (KAATSU exercise), has been reported to substantially increase serum GH concentrations [Abe et al., 2005b; Takarada et al., 2000; Takano et al., 2005].

A variety of factors are thought to influence the KAATSU-induced GH secretion, such as muscle metabolic demands and hypoxia. Although the precise mechanism is not fully understood, sympathetic nerve signals sent by metabolic receptors from working muscle seem to play an important role in stimulation of KAATSU-induced GH release [Takarada et al., 2000; Takano et al., 2005]. When the activation of chemoreceptors during exercise is proportional to the exercise intensity per unit of muscle mass, serum GH responses to acute exercise differ between muscle groups of different size. In this line, GH responses to acute exercise may be greater during lower body exercise when compared to the upper body exercise.

A previous study [Kozlowski et al., 1983] reported that greater increases in serum GH concentration accompanied arm (smaller muscle group) exercise than those observed during leg exercises performed at equivalent oxygen uptake. However, in that study, the intensity of their arm exercise was not similar to leg exercise when performed at the same absolute oxygen uptake, since peak oxygen uptake during arm exercise is 30% lower when compared with leg exercise, resulting in a higher exercise intensity for the arm exercise. Therefore, it is not clear whether resistive exercise combined with or without KAATSU would produce differences in GH secretion between arm and leg exercise performed at the same exercise intensity. Thus, the purpose of the present study was to compare the GH responses to acute KAATSU resistance exercise in either arm or leg muscle exercise.

SUBJECTS and METHODS

Subjects

Five recreationally active male volunteers aged 24-28 years (26.0 ± 1.8 years) with a body mass index of 23.6 ± 1.1 kg/m^2 were studied. None of the subjects had any history of relevant medical illness or were taking medication. All subjects were informed of the procedures, risks, and benefits, and signed an informed consent document before participation. The Tokyo Metropolitan University Ethics Committee for Human Experiments approved the study.

Experimental design and exercise protocols

The subjects participated in two types of exercise tests on separate days within a week interval: 1) arm exercise (arm curl and triceps press down), 2) leg exercise (squat and leg curl). All tests were performed after a 4 h fast in the afternoon. After 30 min of rest, pre-testing blood samples were collected. The subjects then performed 30 repetitions of arm or leg exercise of 20% of a pre-determined 1-RM. Following a 30 sec rest period, the subjects then performed three sets of 15 repetitions, with each set and exercise separated by 30 sec rest period.

Restriction of muscular venous blood flow by KAATSU

A method for inducing the restriction of muscular venous blood flow has been previously reported [Abe et al. 2005a]. Briefly, the subject wore an air pressure belt (30 mm wide for the arm and 45 mm wide for leg, Kaatsu Master, Sato Sports Plaza, Tokyo, Japan) placed around the most proximal portion on both arms or on both legs during the corresponding exercise. Resting systolic blood pressure (SBP) of the arm (at heart level) was measured using an automatic sphygmomanometer (Fit Cuff, Omron, Tokyo, Japan), and SBP of the leg was estimated as follow: leg SBP = 120% of arm SBP. The external restriction pressure was selected 50% higher than each of the SBP, i.e., 190 mmHg for arm and 230 mmHg for leg, when arm SBP is 125 mmHg. Restriction of muscle blood flow was maintained for the entire exercise session, including the rest periods. The belt pressure was then released immediately upon completion of the session.

Blood sampling and biochemical analysis

Venous blood samples were obtained prior to the start of exercise, immediately post exercise, and 15- and 60-min after exercise. Blood lactate concentrations (LA) were determined using a portable analyzer (Lactate Pro, Arkray, Kyoto, Japan). Serum GH concentration was measured with a commercially available radioimmunoassay (S.R.L. Inc., Tokyo, Japan). Plasma noradrenaline concentration was measured by means of high-performance liquid chromatography (HPLC) with electrochemical detection. Hematocrit was measured in duplicate by microcentrifugation. Serum albumin and Na/K concentrations were also measured by bromcresol purple and by ion-selective electrodes, respectively. Relative change in plasma volume was calculated in accordance with a previous formula (van Beaumont et al., 1973).

Statistical analyses

Results are expressed as means ± standard deviation (SD) for all variables. The effects of arm KAATSU-exercise compared to leg KAATSU-exercise on changes in blood parameters over time (exercise and post-exercise time) were tested by a two-factor ANOVA for repeated measurements. Further analysis used Student's paired t-test if the interaction, time x group, was significant. Statistical significance was set at $P<0.05$.

RESULTS

Blood lactate, noradrenaline and growth hormone

A significant main effect for time was determined for blood LA ($P<0.001$, Fig.1) and serum GH ($P<0.001$, Fig. 3). Post hoc analyses indicated that for the two variables, significant elevations were apparent immediately post and 15-min after exercise for LA and at immediately post, 15- and 60-min after exercise for GH in both arm and leg KAATSU-exercise. A significant group x time interaction was observed for plasma noradrenaline ($P<0.001$, Fig. 2). Post hoc analyses indicated that leg KAATSU-exercise resulted in a significantly greater increase in noradrenaline levels when compared to arm KAATSU-exercise immediately post exercise.

Parameters of plasma volume change

A significant main effect for time was observed for limb girth ($P<0.001$) and hematocrit ($P<0.001$, Table 1). Post hoc analyses indicated that upper-arm and thigh girths were increased immediately post, and 15- and 60-min after exercise. Also, hematocrit was elevated immediately post exercise following both trials, and 15-min after exercise during arm KAATSU-exercise. A significant group x time interaction was observed for serum albumin concentration ($P=0.037$),

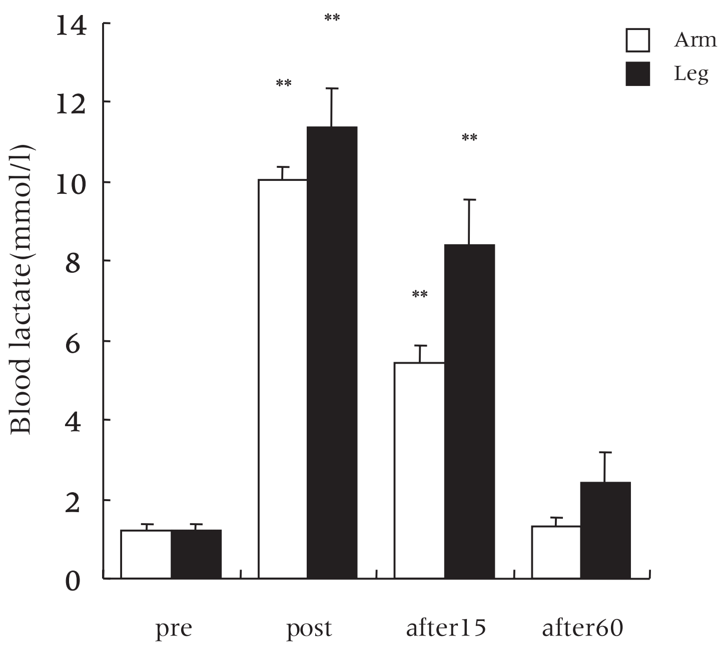

Figure 1. Blood lactate concentrations in response to acute low-intensity resistance exercise combined with KAATSU. Significant differences from pre-exercise, ** $P < 0.01$.

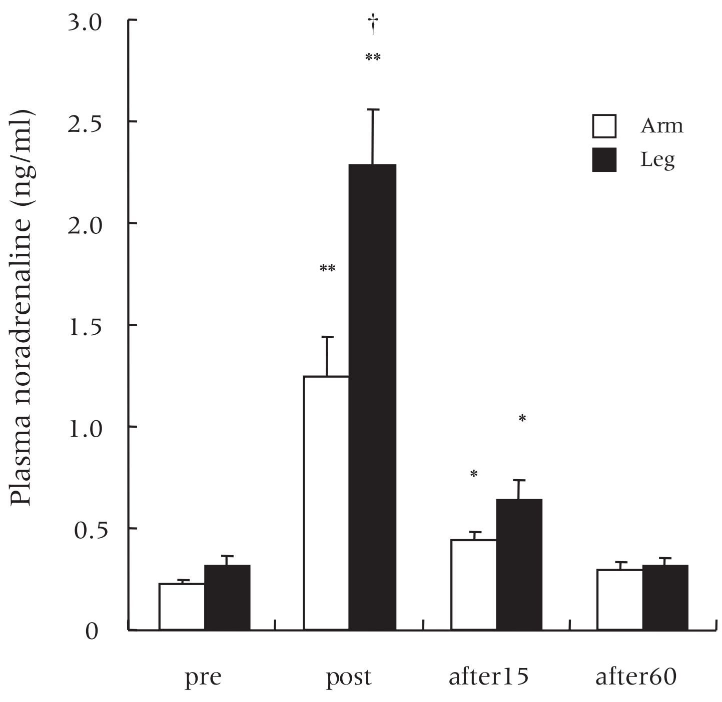

Figure 2. Plasma noradrenaline concentrations in response to acute low-intensity resistance exercise combined with KAATSU. Significant differences from pre-exercise, * $P < 0.05$, ** $P < 0.01$. Significant difference between arm and leg exercise, † $P < 0.01$.

Table 1. Limb girth, hematocrit, albumin and Na/K concentrations in response to acute low-intensity resistance exercise combined with KAATSU

	Pre	Post	15-min	60-min
Arm				
Upper arm girth (cm)	30.0 (1.4)	32.2 (1.9)†	31.8 (1.6)†	31.1 (1.6)†
Hematocrit (%)	43.5 (0.7)	49.5 (1.2)†	45.6 (1.3)*	44.0 (0.5)
Na (mEq/L)	141 (2)	142 (3)	140 (2)	141 (2)
K (mEq/L)	4.5 (0.4)	3.9 (0.3)	3.9 (0.2)	4.4 (0.5)
Albumin (g/dl)	5.1 (0.4)	5.9 (0.3)†	5.2 (0.3)	4.9 (0.2)
Leg				
Thigh girth (cm)	56.0 (2.7)	58.0 (2.7)†	57.2 (2.5)†	56.9 (2.5)†
Hematocrit (%)	44.9 (1.2)	49.7 (1.1)†	46.4 (2.2)	44.9 (0.9)
Na (mEq/L)	141 (2)	144 (3)	142 (2)	141 (1)
K (mEq/L)	4.1 (0.3)	3.9 (0.4)	4.0 (0.7)	4.5 (0.6)
Albumin (g/dl)	5.1 (0.2)	5.7 (0.2)†	5.4 (0.1)*	5.0 (0.2)

Significant differences from pre-exercise, *P<0.05 †P<0.01

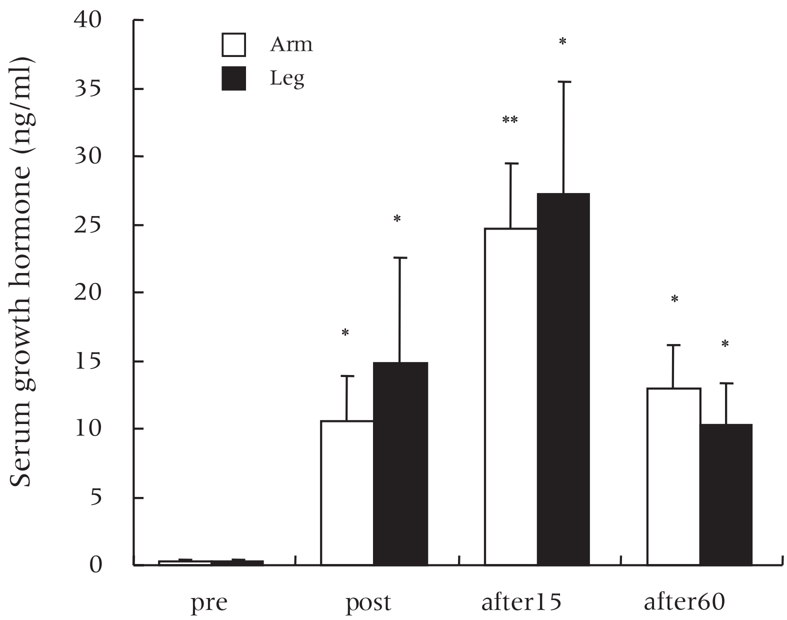

Figure 3. Serum growth hormpne concentrations in response to acute low-intensity resistance exercise combined with KAATSU. Significant differences from pre-exercise, * $P < 0.05$ ** $P < 0.01$.

however a post hoc analyses showed no significant differences over time. Relative change in plasma volume after exercise was not significantly different between arm (-21%) and leg (-17%) exercise.

DISCUSSION

It is well known that exercise is a potent stimulus for GH secretion, especially high-intensity exercise. However, it is not clear whether exercise-induced GH release differs between upper-body and lower-body exercise. Our findings demonstrated that the notable increases in serum GH response to resistive exercise with KAATSU was observed in both arm and leg exercise. Furthermore, there was no significant difference between the muscle groups in GH response. In addition, the magnitude of the increases in arm and leg exercise was consistent with previous KAATSU studies [Takarada et al., 2000; Takano et al., 2005]. In contrast, a previous study [Kozlowski et al., 1983] reported a greater increase in plasma GH concentration following arm exercise when compared to leg exercise performed at equivalent absolute oxygen uptake. However, in that study, the relative exercise intensity for the arm was higher compared with leg exercise, since peak oxygen uptake during arm exercise is 30% lower than that of leg exercise [Sanada et al., 2005]. In fact, Kozlowski and colleagues (1983) reported a greater increase in heart rate and blood lactate concentration during and after the arm exercise compared with those of the leg exercise. Therefore the difference in exercise intensity between the arm and leg exercise, and not any intrinsic difference between muscle groups per se, may be the reason for the larger GH response in arm exercise. In the present study, using an exercise intensity of 20% of 1-RM and a restriction stimulus of 150% of resting systolic blood pressure to the working muscle resulted in similar GH responses for both the arm and leg exercise. Our results suggest that the GH secretory responses to exercise may be similar between muscle groups of different size when performed at equivalent exercise intensity.

In the present study, we found that post exercise blood lactate concentrations were similar between arm and leg exercise with KAATSU. These results suggest that blood lactate could serve as a marker for exercise-induced GH release, since there was a similar increase in GH observed after exercise. However, a previous study [Luger et al., 1992] reported the effect of sodium L-lactate intravenous infusion on plasma GH concentration (doses producing blood lactate concentrations within the range of those seen between 70% and 90% Vo2max), and found that the elevation of plasma GH was smaller than those obtained at an exercise-induced matched blood lactate concentration. Changes in blood lactate and catecholamine release followed similar patterns of response to exercise [Weltman et al., 1994; Schneider et al., 2000], therefore, it is unlikely that blood lactate itself is responsible for the GH response to KAATSU exercise and would be a poor surrogate marker for GH.

Noradrenaline is one of several markers that have been suggested as an explanation for exercise-induced GH release. For example, in vitro animal studies found that catecholamines can directly stimulate GH secretion from pituitary tissue [Giustina and Veldhuis, 1998]. In humans, when exercise intensity is increased from 25% to 175% of an individual's lactate threshold, the change in serum GH is linearly related to changes in plasma noradrenaline concentrations [Weltman et al., 2000]. In the present study, however, noradrenaline concentrations were significantly lower in the arm exercise than in the leg exercise, despite the fact that there was no difference in GH responses between the arm and leg exercise. Our findings differ from previous reports [Giustina and Veldhuis, 1998; Weltman et al., 2000], but at the same time, support the concept that the increase in plasma noradrenaline after exercise depends on the size of the muscle mass utilized [Seals and Victor, 1991]. It is clear that further studies are needed to clarify the basic mechanisms of GH release that is stimulated by arm or leg KAATSU exercise.

In conclusion, there were no significant difference in serum GH concentrations following arm and leg KAATSU exercise. These results suggest that exercise-induced GH secretion may be similar between the arm and leg exercise performed at equivalent exercise intensity and restriction stimulus.

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