

Electromyographic responses of arm and chest muscle during bench press exercise with and without KAATSU

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The purpose of this study was to compare the EMG activity of blood flow restricted (limb) and non-restricted (trunk) muscles during multi-joint exercise with and without KAATSU. Twelve (6 women and 6 men) healthy college students [means (SD) age: 24.1 (3.5) yrs] performed 4 sets (30, 15, 15, and 15 reps) of flat bench press exercise (30% of a predetermined one repetition maximum, 1-RM) during two different conditions [with KAATSU and without KAATSU (Control)]. In the KAATSU condition, a specially designed elastic cuff belt (30 mm wide) was placed at the most proximal position of the upper arm and inflated to a pressure of 100% of individual's resting systolic blood pressure. Surface EMG was recorded from the muscle belly of the triceps brachii (TB) and pectoralis major (PM) muscles, and mean integrated EMG (iEMG) was analyzed. During 4 sets of the exercise, gradual increases in iEMG were observed in both TB and PM muscles for the KAATSU condition. The magnitude of the increases in iEMG in the TB and PM muscles were higher ($P < 0.05$) with KAATSU compared to the Control condition. In the first set, the mean exercise intensity from normalized iEMG was approximately 40% of 1-RM in both Control and KAATSU conditions. However, the mean exercise intensity of both muscles were 60-70% of 1-RM for the KAATSU condition and only about 50% of 1-RM for the Control condition, respectively, during the fourth set. We concluded that increases in iEMG in the trunk muscle during KAATSU might be an important factor for KAATSU training-induced trunk muscle hypertrophy.

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INTRODUCTION

A number of publications have reported that low-intensity exercise training combined with KAATSU training (restriction of muscular venous blood flow from the limb muscles) can result in significant and rapid increases in muscle size and strength in the arm and thigh muscles (Burgomaster et al., 2003; Kawada and Ishii, 2005; Shinohara et al., 1998; Takarada et al., 2000; 2002). To the best of our knowledge, only one study has focused on KAATSU training-induced trunk muscle hypertrophy. They reported that muscle hypertrophy occurred not only in the limb muscle but also in the trunk muscle following KAATSU resistance training (Abe et al., 2005). The results of previous studies indicate that muscle hypertrophy can occur in blood flow restricted limb muscle, and also in non-restricted trunk muscle following multi-joint KAATSU resistance training, however, the mechanism for this adaptation is not fully understood.

Resistance exercise with restricted muscular blood flow has been shown to result in an increase in the integrated electromyogram (EMG) of the active limb muscle (Moritani et al., 1992; Takarada et al., 2000; 2002), and this response is an important factor for KAATSU training-induced limb muscle hypertrophy (Takarada et al., 2000; 2002). Under these

conditions, synergistic action between limb and trunk muscles may occur during the multi-joint KAATSU resistance exercise. Therefore, we hypothesized that increases in EMG activity during KAATSU resistance exercise could be achieved not only in the limb muscle but also in the trunk muscle. Thus, the purpose of this study was to compare the EMG activity of the blood flow restricted (limb) and non-restricted (trunk) muscles during multi-joint exercise with and without KAATSU.

METHODS

Subjects

Twelve (6 women and 6 men) healthy college students [age, 24.1 (3.5) yrs; height, 167.5 (8.4) cm; weight, 61.8 (11.2) kg, means (SD)] with no previous resistance training experience volunteered for the study. All subjects were informed of the procedures, risks, and benefits, and signed an informed consent document before participation. The study conformed to all standards for the use of human subjects in research as outlined in the Helsinki declaration and was approved by the Tokyo Metropolitan University Ethics Committee for Human Experiments.

Experimental design and exercise protocols

The subjects participated in two conditions [with

KAATSU and without KAATSU (Control)] of flat bench press exercise in random order (about 5 hours interval between the conditions). A supinated grip at the standard grip position (160% of biacromial distance) was used (Lehman 2005). The subjects performed 30 repetitions (approximately constant velocity in 2.4 sec, 1.2 sec for the eccentric phase and 1.2 sec for the concentric phase) of bench press exercise at 30% of a pre-determined one repetition maximum (1-RM). Following a 30 sec rest period, the subjects then performed three sets of 15 repetitions, with each set separated by a 30 sec rest period (Abe et al., 2005; Sato et al., 2005).

Restriction of muscular blood flow by KAATSU

A specially designed elastic belt (30 mm wide) was placed around the most proximal portion of each upper arm during KAATSU testing only. The belt contained a pneumatic bag along its inner surface that was connected to an electronic air pressure control system that monitored the restriction pressure (Kaatsu-Mater, Sato Sports Plaza Ltd., Tokyo, Japan). Prior to the KAATSU testing, the subjects were seated on a chair, the belt air pressure was set at 60 mmHg for 30 s, and the air pressure was released. The air pressure was increased by 20 mmHg and held for 30 s, then released for 10 s between occlusive stimulations. This process was repeated until a final restriction pressure of 100% of an individual's resting systolic blood pressure was reached. This pressure was then maintained for the entire exercise session, including the rest periods. The belt pressure was released immediately upon completion of the session. Resting systolic blood pressure of the arm (at heart level) was measured using an automatic sphygmomanometer (Fit Cuff, Omron, Tokyo, Japan)

before KAATSU testing.

EMG measurement and analysis

EMG activities of the triceps brachii (TB) and pectoralis major (PM) muscles were measured with bipolar surface electrodes (Vitrode F, Ag/AgCl, 1-cm diameter, Nihon Kohden, Tokyo, Japan) placed on each muscle with a fixed 2-cm inter-electrode distance (center to center). Prior to electrode placement, the skin area was polished with skin preparation gel and cleaned with ethanol in order to reduce skin impedance and to ensure good adhesion of the electrodes. The EMG signals were sampled via differential amplifiers (Nihon Kohden AB-621G, Tokyo, Japan) at 1000 Hz for each muscle (Figure 1). Raw EMG signals were digitized and stored on hard disk in a computer by the Chart software program, version 4.2 (AD Instruments Pty Ltd, Australia). Digital rectification and integration of EMG (iEMG) data were performed with the same computer.

Normalized iEMG and relative exercise intensity determination

To determine the relative exercise intensity during bench press exercise with and without KAATSU for each set, a correlation between relative lifting load (20, 30, 40, 50, 60, and 70% of 1-RM, 5 repetitions for each load) and corresponding iEMG was measured for each subject before testing. Using the regression line between lifting load and iEMG (Figure 2), the relative intensity was calculated from iEMG data during bench press exercise with and without KAATSU.

Statistical analyses

All values are expressed as means (standard

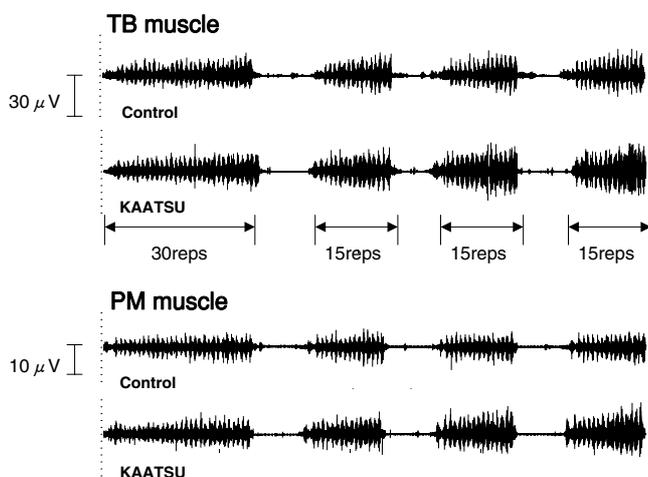


Figure 1. Typical examples of EMG signals recorded from triceps brachii (TB) and pectoralis major (PM) muscles during low-intensity flat bench press exercise with and without KAATSU.

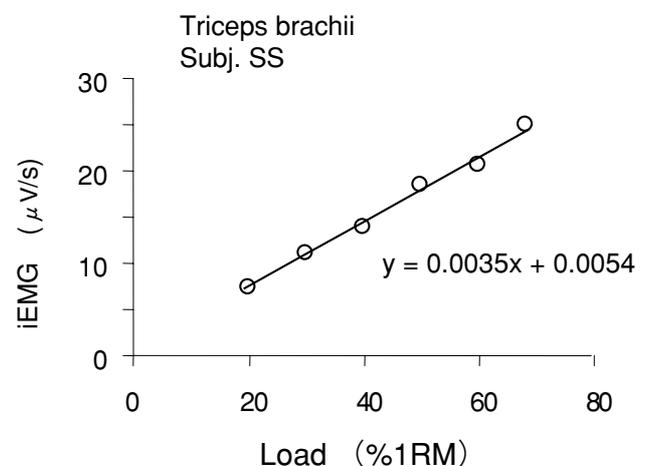


Figure 2. Relationship between relative lifting load and mean iEMG during bench press exercise (subject SS). The relative exercise intensity during bench press with and without KAATSU was calculated using the regression line.

deviations) for all variables. Statistical analyses were performed by a two-way analysis of variance (ANOVA) with repeated measures [Condition (Kaatsu and Control) x Time (sets)]. Post-hoc testing was performed by a student's paired t-test. Statistical significance was set at $P < 0.05$.

RESULTS

A significant condition x time interaction was observed for the normalized mean iEMG in TB and PM muscles ($P < 0.01$, Figure 3). Post hoc analyses indicated that KAATSU bench press resulted in a significantly greater ($P < 0.05$ or $P < 0.01$) increase in mean iEMG activity when compared to the Control bench press. During the first 30 reps of bench press, mean exercise intensity from the normalized iEMG was approximately 40% of 1-RM in both Control and KAATSU conditions. In the third set of 15 reps, the mean exercise intensity was 60-70% of 1-RM in both TB and PM muscles for the KAATSU condition and only about 50% of 1-RM in both muscles for the Control condition. There was no gender difference in

iEMG activity during bench press exercise with and without KAATSU (data not shown).

DISCUSSION

It is known that low-intensity resistance exercise with restricted venous blood flow (KAATSU) (Takarada et al., 2000; 2002) or occluded blood flow (Moritani et al., 1992) has been shown to result in an increase in the integrated EMG of the active limb muscle. However, it is unknown whether the increase in EMG activity during multi-joint exercise with KAATSU or blood flow occlusion could be achieved, not only in the limb muscle, but also in trunk muscles. Our findings demonstrated that increases in iEMG activity was observed in both limb (triceps brachii) and trunk (pectoralis major) muscles during low-intensity KAATSU bench press exercise. The results of this study support our hypothesis that EMG activity is increased by the synergistic action of blood flow restriction in both limb muscles and non-restricted trunk muscles in the shoulder joint. KAATSU exercise-induced increases in EMG activity in the trunk muscle may be one of the important factors for the muscle hypertrophy seen in the trunk muscle following low-intensity KAATSU resistance training in a previous study (Abe et al. 2005).

Blood flow restriction pressure (belt air pressure) is an important variable for determining the exercise intensity during KAATSU exercise (Abe et al., 2006). A previous study reported that increase in EMG activity depends on blood flow restriction pressure during a constant load of KAATSU exercise (Yasuda et al. 2006). In the present study, the restriction pressure was set at 100% of individual's resting systolic blood pressure (approximately 110 mmHg), resulting in blood lactate concentrations measured immediately after the KAATSU exercise to increase to about 4 mmol/L (data not shown). Previous KAATSU-training studies have used similar or even higher restriction pressures compared to the present study which resulted in blood lactate concentrations to rise to about 10 mmol/L after low-intensity KAATSU exercise (Sato et al., 2005; Takarada et al., 2000). During exercise with highly restricted blood flow from the working muscle, the EMG activity may be increased to a greater extent than exercise alone, which would recruit more fast-twitch fibers and their higher threshold motor units in both arm and trunk muscles during multi-joint KAATSU exercise. Therefore, our results support the previous findings of muscle hypertrophy seen in the trunk muscle following multi-joint KAATSU exercise training (Abe et al. 2005).

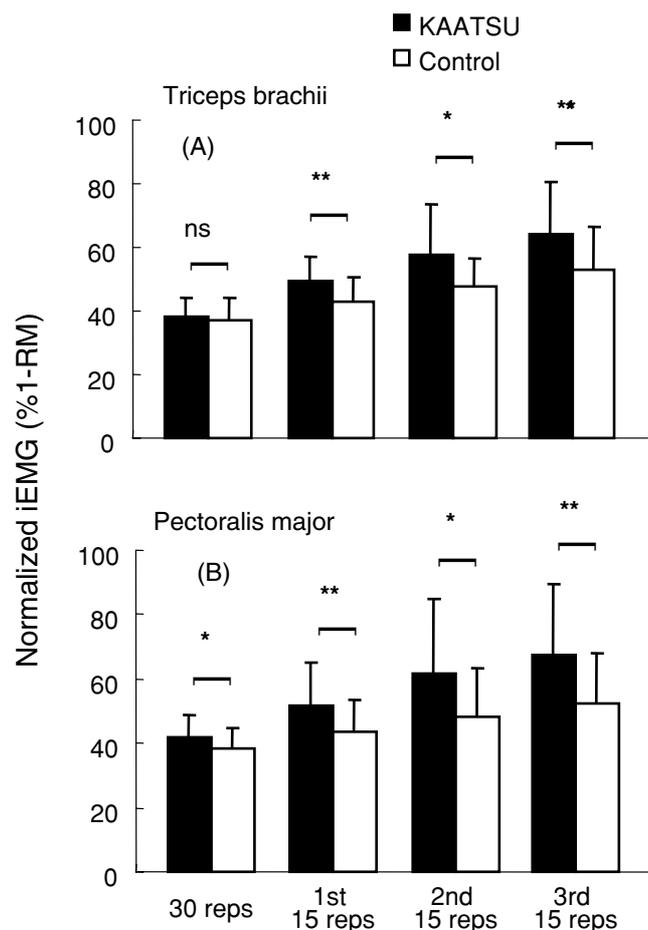


Figure 3. Changes in exercise intensity determined by normalized iEMG during 4 sets of bench press exercise with and without KAATSU. * $P < 0.05$, ** $P < 0.01$, KAATSU vs. Control

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