

Low-intensity kaatsu resistance exercises using an elastic band enhance muscle activation in patients with cardiovascular diseases

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We examined the effects of blood flow-restricted, low-intensity resistance exercise (termed kaatsu), using an elastic band for resistance, on muscle activation in patients with cardiovascular diseases. Six patients with cardiovascular diseases [male, 69 ± 12 (SD) years old, five old myocardial infarction and one dilated cardiomyopathy] performed biceps flexion exercises (four sets) using an elastic band for resistance with blood flow restriction [BFR (kaatsu training)] or CON (unrestricted blood flow). During a BFR (kaatsu training) session, subjects wore a kaatsu belt inflated to 110–160 mmHg on the proximal region of both arms. Surface electromyography (EMG) was recorded from the biceps brachii muscles, and mean integrated EMG (iEMG) was analyzed. Ratings of perceived exertion (RPE) were measured using the Borg scale immediately after the last set of each exercise (Post). During exercises, muscle activation increased progressively under BFR (kaatsu training) (approximately 40%), but not under CON; muscle activation was higher under BFR (kaatsu training) than that under CON in all exercises ($P < 0.001$). RPE at Post was also higher ($P < 0.05$) under BFR (kaatsu training) than that under CON in all exercises. RPE at Post was significantly correlated with increased iEMG in biceps flexion exercises ($r = 0.68$, $P < 0.001$). We conclude that kaatsu training using elastic bands for resistance enhances muscle activation in patients with cardiovascular diseases and may be an effective method to promote muscle hypertrophy in patients with cardiovascular diseases.

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INTRODUCTION

Muscle wasting results from sarcopenia due to aging and from cachexia caused by diseases such as chronic heart failure (CHF), chronic obstructive pulmonary disease (COPD), cancer, chronic kidney disease and other diseases (Thomas 2007). Above all, CHF is a disease of remarkable muscle wasting, and preventing it by exercise training is important. Nakajima et al. (2010) recently reported that low-intensity kaatsu resistance exercises safely increase the muscle strength/mass and endurance capacity in patients with ischemic heart disease. Kaatsu training using a low-intensity resistance exercise appears to be a promising and useful resistance method for cardiac rehabilitation.

According to the American College of Sports Medicine guidelines, the conditions for inducing muscle hypertrophy and increasing muscle mass are as follows: (1) More than 65-70% work load of one repetition maximum (1-RM) is needed. (2) Three to four sets until exhaustion. (3) Frequency is two-three times per week. However, such high-intensity loads cannot be applied to patients with diseases, especially to patients with cardiovascular diseases and to elderly

patients. In the past decade, several studies have reported that muscle hypertrophy can be produced with low-intensity (20–30% 1-RM) kaatsu training, regardless of age (Takarada et al. 2000; Abe et al. 2006; Fujita et al. 2007). As this type of exercise does not require lifting heavy weights, it might be a feasible method for cardiac rehabilitation requiring resistance exercise (Pollock et al. 2000; Balady et al. 2007).

As an elastic band is inexpensive, compact, and easy to use compared with machines/free weights, elastic band resistance training is feasible for use in home-based training programs for older subjects or for patients with a lower level of activity (Zion et al. 2003; Ribeiro et al. 2009; Colado et al. 2010). We examined the effects of low-intensity kaatsu exercise using an elastic band for resistance on muscle activation in patients with cardiovascular diseases.

MATERIALS AND METHODS

Subjects

Six patients with cardiovascular diseases [male, 69 ± 12 years old, five old myocardial infarction and one dilated cardiomyopathy] participated in this study. Left ventricular ejection fraction was $55 \pm 10\%$ by

ultrasonic cardiogram. All subjects received a verbal and written description of the study and provided written, informed consent prior to participating in the study. This study was approved by the Ethics Committee of the University of Tokyo.

Protocol

One week prior to experiments, all subjects completed an orientation session, which included familiarization with BFR and the elastic band exercises using the “medium” bands (i.e., Red Thera-Bands; Hygenic Corporation; Akron, Ohio, USA) for 5 subjects and the “thin” band (i.e., Yellow Thera-Band) for 1 subject. During the orientation session, subjects sat in a chair with the testing arm placed on a table at heart level. During biceps flexion exercise, subjects were seated comfortably on a chair. Both exercises were performed using an elastic band. The exercise duration was 2.4 sec and included a 1.2-sec concentric and 1.2-sec eccentric exercise cycle controlled by a metronome (50 beats/min). The exercise session (30 repetitions followed by three sets of 15 repetitions, with rest periods of 30 sec between sets and exercises) was determined based on previous studies (Yasuda et al. 2009, 2012).

BFR

In the orientation session, all subjects received instructions on how to wear the kaatsu belt (30-mm width; Kaatsu-Master, Sato Sports Plaza, Tokyo, Japan) at the most proximal region of both arms. Prior to exercise with BFR, subjects were seated on a chair and the kaatsu arm cuff was tightened around the arm to a belt pressure of 40 mmHg. The cuff was then inflated to a pressure of 100 mmHg for 30 sec and then deflated for 10 sec. This procedure was repeated, until the final cuff restriction pressure of 110–160 mmHg was achieved. Once the cuffs were inflated, they remained inflated for the entire experimental session, including rest periods between sets and exercises.

ELECTROMYOGRAPHY (EMG)

The skin was abraded with a skin preparation gel (Skinpure, Nihon Kohden, Tokyo, Japan), and cleaned with alcohol wipes. During the experiment, skin impedance was less than 2 k Ω . The ground electrode was positioned on the lateral epicondyle. Bipolar (1-cm center-to-center) surface EMG (sEMG) electrodes (Ag/AgCl; Vitrode F; Nihon Kohden) were placed along the longitudinal axis of the biceps brachii of the left upper arm. The electrode placement on the biceps brachii was at the mid position of the upper arm limb length. EMG signals were recorded and collected on a personal computer for subsequent analysis. All EMG signals were digitized at a sampling rate of 1024 Hz with a bandwidth of 0 Hz–500 kHz (AB 6216; Nihon Kohden). To determine integrated EMG (iEMG),

signals were fully rectified and integrated (Power Lab Chart 7 software, ADInstruments, Nagoya, Japan). During the experimental session, sEMG was recorded continuously, and each repetition was analyzed individually for iEMG. iEMG values were divided into groups of five successive repetitions, and the average value for each group of five repetitions was represented as a single data point for statistical analysis. To determine the iEMG ratio of agonist muscles, iEMGs during each exercise were normalized to Pre, which were iEMGs without BFR before the first set of each exercise. RPE was measured using the Borg scale immediately after the last set of each exercise (Post) (Borg 1973).

STATISTICAL ANALYSIS

Results are expressed as means \pm standard deviation (SD). A two-way analysis of variance with repeated measures (condition / time) was used to evaluate the training effects for all dependent variables. Post-hoc testing was performed using Tukey’s technique when appropriate. All calculations were made with JMP statistical software package v.9.0 (SAS Institute Inc., Tokyo, Japan). Pearson’s product correlation was used to determine the relationship between change in iEMG and RPE. Statistical significance was set at $P < 0.05$.

RESULTS

During exercises, muscle activation increased progressively under BFR (approximately 40%, Fig. 1, Fig. 2), but not under CON. Muscle activation was significantly higher under BFR than that under CON in all exercises ($P < 0.001$, Fig. 2). However, during exercises, iEMGs were similar among the last five repetitions of each set under BFR and CON (BFR, 1set, 1.36 ± 0.18 , 2set, 1.37 ± 0.28 , 3set, 1.44 ± 0.16 , 4set, 1.43 ± 0.18 , $P = \text{NS}$; CON, 1set, 0.98 ± 0.19 , 2set, 0.84 ± 0.12 , 3set, 0.86 ± 0.17 , 4set, 0.93 ± 0.11 , $P = \text{NS}$).

RPE at Post was also higher under BFR than under CON in all exercises (BFR vs. CON; 1set, 12.5 ± 0.5 vs. 11.3 ± 0.8 ; 2set, 13.0 ± 1.1 vs. 11.7 ± 1.0 ; 3set, 13.2 ± 1.0 vs. 11.7 ± 1.0 ; 4set, 13.8 ± 1.3 vs. 11.8 ± 1.0 ; all $P < 0.05$, Fig. 3). During exercises, RPE significantly increased progressively under BFR ($P < 0.005$, 4 set vs. 1 set), but not under CON. RPE at Post was significantly correlated with increased iEMG in biceps flexion exercises ($r = 0.68$, $P < 0.001$, Fig. 4).

DISCUSSION

These results suggest that low-intensity kaatsu resistance exercises using an elastic band increase muscle activation in patients with cardiovascular diseases. Low-intensity kaatsu resistance training using an elastic band appears to be a promising and useful resistance method for cardiac rehabilitation.

In our previous study, a significant increase of

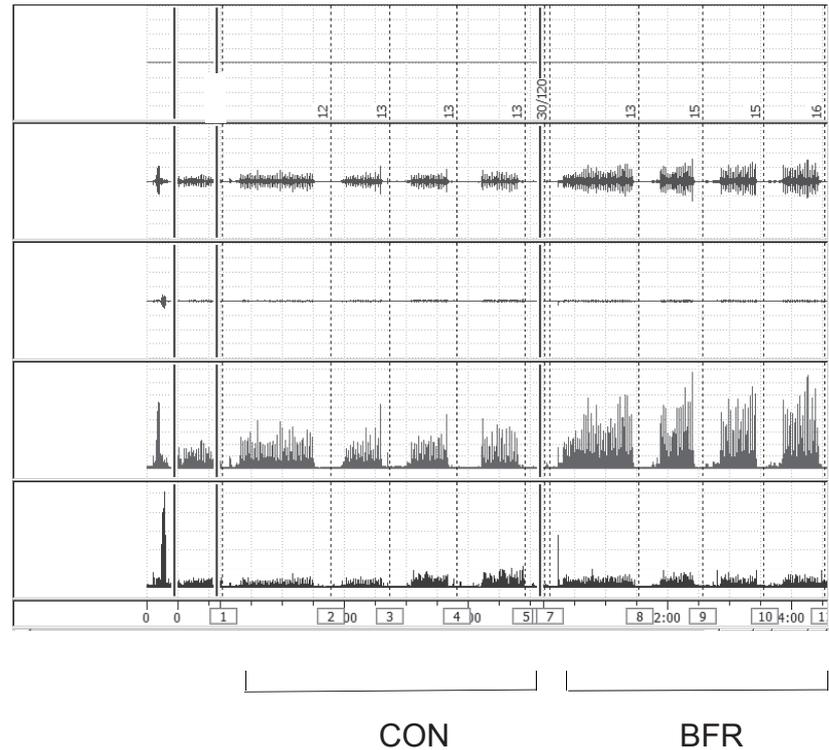


Figure 1. Representative EMG traces from the experiment including 30 repetitive contractions followed by three sets of 15 repetitions. Muscle contractions were biceps curls. CON=control, BFR=blood flow restriction (kaatsu training).

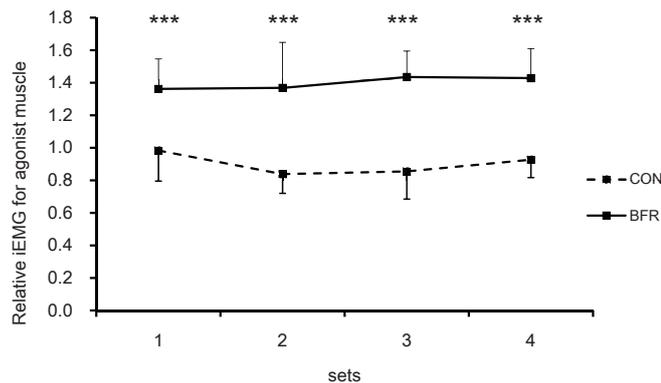


Figure 2. Relative integrated EMG data for agonist muscle in the experiments. Data represent the last five repetitions of each set. CON=control, BFR=blood flow restriction (kaatsu training). ***, $P < 0.001$ vs. CON; Mean \pm SD.

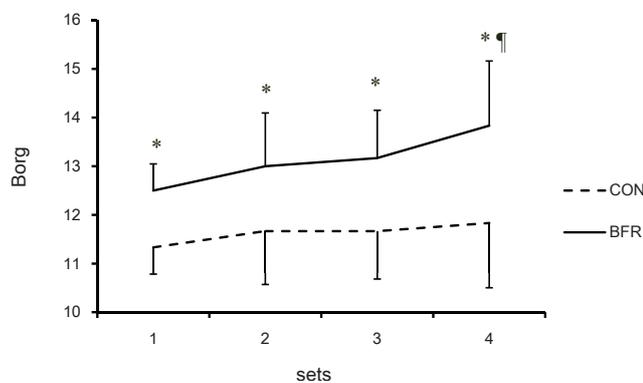


Figure 3. Borg scale after the last set of each exercise. CON=control, BFR=blood flow restriction (kaatsu training). *, $P < 0.05$ vs. CON; ¶, $P < 0.005$ vs. 1 set; Mean \pm SD.

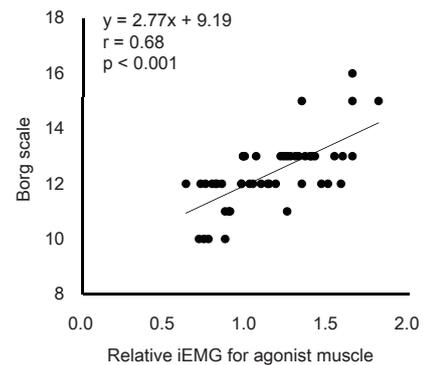


Figure 4. Correlation between relative integrated EMG for agonist muscle in the last five repetitions of each set and Borg scale after the last set of each exercise.

muscle cross-sectional area (CSA) in the quadriceps femoris was observed in patients with ischemic heart disease (Nakajima et al. 2010). Similarly, kaatsu training also increased hamstring and adductor CSA. The estimated thigh CSA in that study increased by approximately 4-10% ($P < 0.05$) following three months of the kaatsu training (2 days per week, 32 total training sessions). Muscle CSA in the quadriceps femoris at 30%, 50% and 70% position of femur length increased 5.1%, 4.6% and 10.4%, respectively. Therefore, the magnitude of the hypertrophic potential (percent increase in muscle CSA divided by total training sessions) in the thigh was about 0.17-0.31% per training session. Recently, Wernbom et al. (2008) reviewed the effects of high-intensity resistance exercise and low-intensity kaatsu resistance exercise

(leg extension) on muscle hypertrophy of the quadriceps femoris in healthy subjects. High-intensity extension exercise two to three times per week, using 80% 1-RM (three to four sets, 6-10 repetitions, interval 60-120 sec), increased the muscle mass by 0.03-0.26% per day and 1-7% per month (3-21% per three months). On the other hand, low-intensity kaatsu training using 20-50% 1-RM (three to four sets, 15-30 repetition, interval 30-60 sec) increased it by 0.04-0.22% per day and 1.2-6.6% per month (3.6-18% per three months). Thus, low-intensity kaatsu resistance training appears to increase muscle mass in a similar way to heavy resistance exercise in healthy subjects. In our previous study, increases of muscle CSA in the quadriceps femoris at mid-thigh were 4.6% per three months (Nakajima et al. 2010), suggesting that even low-intensity kaatsu resistance training may be a useful method for inducing muscle hypertrophy in patients with cardiovascular diseases.

The mechanism by which BFR potentiates the training effect of low-intensity resistance training remains obscure, but it appears to be related, in part, to an increase in muscle activation (Moritani et al. 1992; Takarada et al. 2000; Yasuda et al. 2009). Yasuda et al. (2009) examined muscle activation during low-intensity kaatsu resistance exercise in healthy subjects. Unilateral elbow flexion muscle contractions (20% 1-RM) were performed in their experiment (three to four sets, 15-30 repetitions, interval 30 s) with a moderate restriction of blood flow, complete occlusion of blood flow or unrestricted blood flow (control). In that experiment, the changes in iEMG were greater with moderate restriction of blood flow than in the control but without the apparent contractile metabolic impairment observed with complete occlusion, suggesting that low-intensity muscle contractions with moderate restriction of blood flow leads to more intense activation of the muscle relative to the external load. Meanwhile, recently, the potential mechanisms behind the blood flow restriction stimulus (5 min, 5 repetitions, interval 3 min) in the absence of exercise were investigated (Loenneke et al. 2012). Significant increases in muscle thickness were observed for both the vastus lateralis (6%, $P<0.05$) and rectus femoris (22%, $P=0.001$) along with a significant decrease in plasma volume (15%, $P=0.001$) and the changes in muscle thickness were maintained even after the cuffs had been removed, suggesting that the attenuation of both the muscle atrophy and the decline in strength previously observed with brief applications of blood flow restriction may have been mediated through an acute fluid shift-induced increase in muscle size. Thus, the mechanism by which BFR potentiates the training effect of low-intensity resistance training may in part be related to the acute muscle swelling effects as well as an increase in muscle activation.

Elastic bands/tubing are widely used in rehabilitative

medicine and in health enhancement for resistance training (Zion et al. 2003; Ribeiro et al. 2009; Colado et al. 2010). Elastic bands are also portable, less expensive and easier to use than weight machines/free weights. Elastic resistance training has been shown to be a feasible alternative to high-intensity resistance training (Colado & Triplett 2008; Ribeiro et al. 2009; Andersen et al. 2010). Yasuda et al. (2012) observed that low-intensity, elastic band resistance exercise combined with BFR enhances muscle activation in healthy young subjects. Similar findings were observed in our study using patients with cardiovascular diseases.

Hemostatic and inflammatory responses are major concerns for patients with cardiovascular disease when performing an exercise, because these responses may be related to the cardiovascular events observed during and after strenuous exercise (Womack et al. 2003). However, our previous study showed that applying BFR during low-intensity resistance exercise did not affect exercise-induced changes in markers of hemostasis (D-dimer and FDP) and inflammation (hsCRP) in patients with ischemic heart disease, although the heart rate and plasma noradrenaline concentration were increased (Madarama et al. 2013). Thus, it was suggested that low-intensity kaatsu resistance training using an elastic band was safe as well as effective.

In conclusion, low-intensity kaatsu resistance training using elastic bands enhances muscle activation in patients with cardiovascular diseases and may be an effective method to promote muscle hypertrophy in patients with cardiovascular diseases. Low-intensity kaatsu training using an elastic band may therefore be an effective method to promote muscle hypertrophy in older adults or in patients capable of tolerating only low-load resistance exercise.

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