ORIGINAL ARTICLE

Effects of short-term, low-intensity resistance training with vascular restriction on arterial compliance in untrained young men

S. J. Kim, V. D. Sherk, M. G. Bemben, D. A. Bemben

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Correspondence to:
Debra A. Bemben, PhD,
Professor, Department of Health and Exercise Science,
University of Oklahoma,
1401 Asp Avenue, Room 104,
Norman, OK 73019, USA
Tel: 405-325-2709
Fax: 405-325-0594
dbemben@ou.edu

See end of article for authors' affiliations

Previous studies have shown that low-intensity resistance training with restricted blood flow, known as *KAATSU training*, increases muscle strength and size. Its effects on blood vessel function, however, have not been examined. We compared the effects of a short-term KAATSU resistance training protocol and traditional high-intensity resistance training on muscle strength and blood vessel function in young, untrained men. Male volunteers were randomly assigned to a KAATSU resistance training group (KR, n=10), a traditional resistance training group (RT, n=10), or a KAATSU-only group (K, n=10). Both KR and RT groups trained 3 times per week for 3 weeks doing leg press (LP), knee flexion (KF), and knee extension (KE) isotonic resistance exercises. Training sessions consisted of 5-10 min of warm-up, followed by 2 sets of 10 repetitions at 80% of 1 repetition maximum (1-RM) for the RT group, while the KR group performed the resistance exercises with vascular restriction at a load of 20% of 1-RM. The K group had only the vascular restriction treatment for 3 weeks. Muscle strength (1-RM) and arterial compliance (pulse contour analysis) were assessed at baseline and after training. Both the KR and RT groups did not show changes in arterial compliance of the large or small arteries (P>0.05) after training. There were significant time effects (P<0.05 pre- vs. posttraining); however, resistance training generally resulted in greater relative improvements in strength. Arterial compliance of the large and small arteries was not affected by the either the KAATSU or traditional high-intensity resistance training interventions.

Key words: arterial compliance, blood vessel function, KAATSU training, muscle strength, resistance training

INTRODUCTION

Arterial compliance reflects the ability of an artery to expand and recoil during cardiac contraction and relaxation (Nichols and O'Rourke, 1998). This blood vessel function has important clinical implications as the elasticity of the walls of the major arteries declines with increasing age. The result is an increased stiffness of the arteries, which is an independent risk factor for cardiovascular disease, especially stroke (Lakatta, 1994). There are several noninvasive methods for arterial compliance assessment, including measuring pulse wave velocity, relating the change in artery diameter to the distending pressure using ultrasound and applanation tonometry, and assessing arterial pressure waveforms (Oliver and Webb, 2003). Pulse contour analysis (PCA) uses a modified Windkessel model to analyze components of the diastolic waveform to determine large artery (capacitative) and small artery (oscillatory) compliance (Cohn et al., 1995; Oliver and Webb, 2003). This technique has been validated with invasive measurements (Cohn et al., 1995).

The association of aerobic exercise with enhanced vascular function and reduced risk of cardiovascular disease is well documented (Green et al., 2004; Sui et al., 2007). However, conflicting findings have been reported concerning the effects of resistance exercise on arterial compliance. Reduced arterial compliance and stiffer arteries were found in resistance-trained men in several cross-sectional studies (Bertovic et al., 1999; Miyachi et al., 2003; Otsuki et al., 2007) and in intervention studies (Kawano et al., 2006; Miyachi et al., 2004). In contrast, central arterial compliance was unchanged after 12 weeks of whole-body resistance training in young men (Rakobowchuk et al., 2005) and after 12 weeks of lower-body resistance training in older men (Maeda et al., 2006). Although the underlying cause for decreased arterial compliance with resistance training is unclear, alterations in the arterial wall structure in response to large blood pressure increases and increased sympathetic nervous system activity have been discussed as potential mechanisms for the resistance training effect (Miyachi et al., 2004).

In recent years, a number of studies have demonstrated that short-term, low-intensity resistance exercise (i.e., 20% 1-repetition maximum [1-RM]) combined with vascular restriction

(KAATSU) increases muscle strength and hypertrophy (Abe et al., 2005; Abe et al., 2006; Takarada and Ishii, 2002; Takarada et al., 2000b). The underlying mechanisms for these physiologic effects are not well understood, but increased muscle fiber recruitment and enhanced endocrine responses may cause improved muscle strength and size (Takarada et al., 2000a). In addition to its effects on muscle, KAATSU training affects hemodynamic response, as the acute application of pressure to the upper thighs with the KAATSU belts has been shown to cause pooling of blood in the legs, thereby decreasing venous return, reducing cardiac output, and increasing total peripheral resistance (Iida et al., 2005). The safety of training in restricted blood flow conditions is a concern as there is a possibility that muscle damage or cell necrosis may be caused by the formation of thrombi or by the no-flow phenomenon (Kawada, 2005). Yet, the incidence of serious adverse effects, such as venous thrombus and pulmonary embolism, is low. Nakajima et al. (2006) concluded that KAATSU training is a safe and promising method for both healthy and clinical populations, including those with cerebrovascular disorders, cardiovascular disease, and orthopedic problems. On the other hand, Takano et al. (2005a, 2005b) recommended that KAATSU training be performed carefully in patients with cardiac disease, such as ischemic heart disease, severe aortic stenosis, and hypertrophic obstructive cardiomyopathy.

Low-intensity resistance training with restricted muscle blood flow would have obvious advantages for individuals who may exhibit limited strength or health-related risks with higher resistance training loads, such as older adults and clinical populations (Karabulut et al., 2007). No studies to date have examined arterial compliance responses to low-intensity resistance training with restricted blood flow. Most resistance exercise studies examining arterial compliance have conducted training for at least 3 months. Therefore, there is a paucity of information on the effects of short-term resistance training on arterial compliance. The purpose of this study was to investigate the effects of a 3-week low-intensity resistance training program with vascular restriction on arterial compliance in healthy, young, untrained men. KAATSU-only and high-intensity resistance training groups were included as comparison groups. We hypothesized that arterial compliance responses would differ in the KAATSU resistance training (20% of 1-RM) and traditional high-intensity resistance training groups (80% of 1-RM) as a result of the large differences in exercise intensity.

METHODS

Subjects

Thirty healthy males between the ages of 18 and 35 years were recruited from the University of Oklahoma and the surrounding Oklahoma City metropolitan area to participate in this study. The subjects had not engaged in a resistance training program for at least 4 months prior to the study. This study was approved by the University Institutional Review Board for Human Subjects, and written informed consent was obtained from each subject.

Experimental Design

All subjects visited the Neuromuscular Laboratory at the University of Oklahoma prior to the first day of physiologic testing to complete the informed consent, health status, calcium intake, and PAR-Q forms. The subjects then were randomly assigned to the low-intensity resistance training group with KAATSU (KR, n=10), the high-intensity resistance training group without KAATSU (RT, n=10), or the KAATSU-only group (K, n=10). Arterial compliance was measured using the HDI/PulseWave™ CR-2000 Research CardioVascular Profiling System (Hypertension Diagnostics, Inc., Eagan, MN, USA) at baseline and after the training programs. On the first day of testing, the subjects completed strength testing for leg press (LP), knee flexion (KF), and knee extension (KE) to determine their training workloads. Each subject in the KR and K groups attended a session to learn about KAATSU training. All subjects were asked to maintain their normal daily physical activities during the training program, which did not include any resistance exercise outside the study. All groups trained for about 20-30 min 3 days per week for 3 weeks. Both the KR and RT groups performed a resistance training protocol consisting of a 5-10-min warm-up (cycling) followed by 2 sets of 10 repetitions at an intensity of 80% of 1-RM for the RT group and 20% of 1-RM for the KR group for the LP, KF, and KE exercises. The KR and K groups underwent the KAATSU (restricted blood flow) procedures.

Strength Testing

Muscle strength for the LP, KF, and KE resistance exercises was assessed by 1-RM procedures at baseline and after the training period. After becoming familiar with the resistance machines, each subject performed 8-10 repetitions at a light load (~50% of predicted 1-RM) as a warm-up. Following a 1-min rest period, the load was increased until the subject was unable to lift it through the full range of motion for a single repetition. The 1-RM was achieved within 5 attempts. If a subject was able to lift the entire weight stack on a machine, then a multiple repetition maximum was used to predict the 1-RM. The multiple repetition maximum was calculated using the following equations of Mayhew et al. (1992):

$\% \text{ of 1-RM} = 52.2 + 41.9 \times e^{(-0.055 reps)}$

1-RM = repetition weight (kg) / (predicted percent 1-RM / 100)

Training Protocols

After a 5-10−min warm-up on a Monark bicycle ergometer (Monark Exercise AB, Vanbro, Sweden), each subject in the KR and K groups wore specially designed elastic cuffs (50 mm width; KAATSU Master, Sato Sports Plaza, Tokyo, Japan) around both thighs at 1-2 cm distal to the inguinal folds. Resting systolic blood pressure (SBP) of the arm was measured to estimate leg systolic blood pressure. Normal resting SBP of the legs is about 20% higher than that of the upper arm. In this study, the final KAATSU pressure was 20% higher than the estimated leg SBP. The cuff pressure used to restrict blood flow was determined with the following equation: KAATSU pressure (mmHg) = (SBP × 1.2) × 1.2.

Prior to the KAATSU training, the subjects were seated on a chair, and the initial cuff pressure was set at about 50 mmHg. Air pressure was increased by 20 mmHg (starting at 120 mmHg), held for 30 s, then released for 10 s until the final pressure for each subject was reached (Abe et al., 2006). Restrictive pressure was maintained throughout the exercise period, which lasted less than 15 minutes, and the pressure was released at the end of the session. The KR subjects performed 2 sets of 10 repetitions at 20% of 1-RM for the LP, KF, and KE resistance exercises. There were 2-min rest periods between exercises and 1-min rest periods between sets. The K group underwent the KAATSU procedures without the exercise protocol for 10 min. The RT group performed 2 sets of 10 repetitions at 80% of 1-RM for the 3 resistance exercises. The exercise protocols are shown in Table 1. The training session attendance was 100% for each group.

Body Composition

Dual energy x-ray absorptiometry (DXA) (GE Lunar Prodigy, Prodigy enCORE 2002 version software 10.50.086, GE Healthcare, Madison, WI, USA) was used to perform a total body scan and measure body composition (% fat, fat mass, bone-free lean body mass, fat-free mass). Subjects were centered in a supine position on the DXA table, with Velcro® straps placed around their knees and ankles. The scan mode setting was based on the subject's truncal thickness: thick (>25 cm), standard (13-25 cm), and thin (<13 cm). A single qualified technician performed all of the total body scans at baseline and after training. The coefficients of variation (CV) for % fat and bone-free lean body mass (BFLBM) of DXA scans were 1.87 and 1.27%, respectively.

Pulse Contour Analysis (PCA)

Arterial compliance was measured using the HDI/PulseWave™ CR-2000 and the CVProfilor® DO-2020 CardioVascular Profiling System (Hypertension Diagnostics, Inc., Eagan, MN, USA). These devices have an oscillometric blood pressure module, a noninvasive Arterial PulseWave™ Sensor, and a 486-75 MHz computer and medical electronics, ncluding a touch screen and software. The subjects came to the laboratory between 7:00 AM and 9:30 AM after an overnight fast of at least 8 hours to avoid potential diurnal variation. The subjects had been instructed to abstain from ingesting caffeine and smoking prior to undergoing these cardiovascular measurements. After height and weight measurements were taken, each

Table 1. Description of exercise protocols

	Groups		
Variables	KR (n=10)	RT (n=10)	K (n=10)
Warm-up (cycling)	5 min	5 min	5 min
Sets and repetitionss	2 / 10	2 /10	No exercise
Workload	20% of 1-RM	80% of 1-RM	10 min with KAATSU
Cuff pressure, mmHg	178.00 ± 19.89	-----	172.00 ± 13.98
Leg press training load, kg	38.59 ± 8.89	157.61 ± 42.54	
Knee flexion training load, kg	19.01 ± 4.64	66.68 ± 13.32	
Knee extension training load, kg	19.87 ± 6.13	75.48 ± 15.61	
Cool-down (cycling)	5 min	5 min	5 min

Data are displayed as means ± SE.

Abbreviations: KR, low-intensity resistance training with vascular restriction group; RT, high-intensity resistance training group; K, vascular restriction only.

subject rested in a supine position on a padded table for approximately 5 min. An appropriate-sized cuff was wrapped around the subject's upper left arm. A rigid plastic wrist stabilizer was placed on the subject's right wrist to minimize movement and stabilize the radial artery during the three 30-s collection of blood pressure waveform data. A noninvasive Arterial PulseWave™ Sensor was positioned on the surface of the skin overlying the right radial artery at the point of strongest pulsation to capture an analog blood pressure waveform. The sensor was adjusted to the highest relative signal strength without occluding the artery. Three consecutive trials were performed. The trials were averaged for the subsequent analyses since one-way analysis of variance (ANOVA) showed no significant differences between the trials.

The large and small arterial compliance measurements were obtained during 30 s of blood pressure waveform collections. Other cardiovascular parameters that were assessed by this instrument during the testing included resting systolic and diastolic blood pressure, resting heart rate (RHR), systemic vascular resistance (SVR), and total vascular impedance (TVI). The subjects were tested at baseline and posttraining. In our laboratory, the coefficients of variation for large artery and small artery compliance variables are 6.7 and 10.6%, respectively, and the intraclass correlation coefficients are 0.918 for large artery compliance and 0.985 for small artery compliance.

Statistical Analysis

All descriptive data are presented as the mean ± SE for the dependent variables. Group differences in baseline values for the dependent variables were determined by one-way ANOVA. Statistical analyses were performed by two-way ANOVA with repeated measures (group [KR vs. RT vs. K] × time [pre vs. post]). If significant group × time interactions occurred, paired *t* tests were used as post hoc tests to determine significant time differences within each group. The percent changes in muscle strength and arterial compliance variables were calculated $\%\Delta = [(\text{post} - \text{pre}) / \text{pre}] \times 100$. One-way ANOVA with the Bonferroni post hoc procedure was used to examine significant group differences in the percent change variables. All statistical procedures were performed by SPSS for Windows 15.0 version (Chicago, IL, USA). The level of significance was set at $P \leq 0.05$.

RESULTS

Subject Characteristics

Table 2 shows the means ± SE for the baseline physical characteristics and body composition variables for each group. There were no significant group differences for the physical characteristics or body composition variables at baseline ($P>0.05$). Also, leg BFLBM did not significantly ($P>0.05$) increase from pre- to posttesting for any group (KR – 19.7 ± 0.9 vs. 20.1 ± 1.0 kg; RT – 18.9 ± 0.6 vs. 19.0 ± 0.6 kg; K – 19.0 ± 0.7 vs. 19.4 ± 0.9 kg).

Muscle Strength

Table 3 shows pre- and posttraining strength values for LP, KF, and KE resistance exercises for each group. There were no significant ($P>0.05$) group differences in the baseline strength values. There were significant time effects for LP ($P<0.05$) and KF ($P<0.01$), with the marginal means increasing from pre- to posttesting (LP – 191.4 ± 9.9 vs. 207.6 ± 12.2 kg; KF – 85.1 ± 3.1 vs. 90.7 ± 3.7 kg). Significant time ($P<0.01$) and group × time interaction ($P<0.01$) effects were detected for KE. Paired *t* tests indicated that both the KR ($P=0.012$) and RT ($P=0.001$) groups had significant increases in KE strength after training, whereas the K group did not exhibit a significant

Table 2. Subject characteristics

	Groups		
Variables	KR (n=10)	RT (n=10)	K (n=10)
Age, yr	25.95 ± 1.62	22.35 ± 0.84	22.31 ± 0.88
Height, cm	176.77 ± 1.98	177.68 ± 1.56	177.70 ± 2.00
Weight, kg	84.55 ± 5.00	75.65 ± 4.40	78.98 ± 5.59
Body fat, %	26.53 ± 2.20	20.09 ± 3.15	23.49 ± 3.32
FM, kg	23.08 ± 2.85	16.26 ± 3.19	19.95 ± 1.86
BFLBM, kg	57.81 ± 2.47	55.92 ± 1.54	55.35 ± 1.86

Data are means ± SE.

Abbreviations: KR, low-intensity resistance training with vascular restriction group; RT, high-intensity resistance training group; K, vascular restriction only; FM, fat mass; BFLBM, bone-free lean body mass.

No significant group differences at baseline (*P*>0.05).

Table 3. Muscle strength at baseline and after 3 weeks of training

	KR (n=10)		RT (n=10)		K (n=10)	
Variables	Pre	Post	Pre	Post	Pre	Post
LP, kg	197.8 ± 13.7	219.8 ± 22.1	195.3 ± 16.9	224.5 ± 20.8	181.2 ± 20.0	178.3 ± 20.6
KF, kg	90.1 ± 7.1	93.3 ± 7.9	82.9 ± 5.2	93.2 ± 6.4	82.3 ± 3.3	85.4 ± 4.2
KE, kg	96.9 ± 7.9	103.8 ± 8.2*	93.5 ± 6.1	111.0 ± 7.6*	88.8 ± 3.6	90.8 ± 3.9

Values are mean ± SE.

Abbreviations: KR, low-intensity resistance training with vascular restriction group; RT, high-intensity resistance training group; K, vascular restriction only; LP, leg press; KF, knee flexion; KE, knee extension.

* $P<0.01$ significant time × group interaction, post > pre.

change for this variable. There was a trend (P=0.067) for a group × time interaction for KF. There were significant group differences ($P<0.01$) in percent changes for KE as the RT group had a significantly greater relative increase compared with the KR and K groups (Figure 1). There were no significant group differences ($P>0.05$) in percent changes for LP strength, but there was a trend (P=0.051) for a significant group effect for percent change in KF strength.

Arterial Compliance and Cardiovascular Variables

Baseline mean values for the arterial compliance and cardiovascular variables did not differ among the 3 groups ($P>0.05$). The large artery and small artery compliance responses to training are depicted in Figures 2 and 3, respectively. There were no significant ($P>0.05$) group, time, or group × time interaction effects for either arterial compliance variable. Table 4 shows the pre- and posttraining means for the blood pressure variables, resting heart rate, systemic vascular resistance (SVR), and total vascular impedance (TVI). There were no significant ($P>0.05$) group, time, or group × time interactions for any of the cardiovascular variables. Also, the percent changes in these arterial compliance and cardiovascular variables after training were not significantly different ($P>0.05$) among the 3 groups (Table 5).

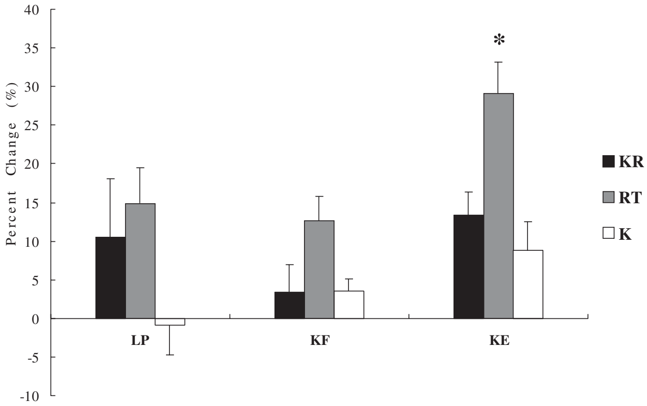

Figure 1. Percent changes in leg press (LP), knee flexion (KF), and knee extension (KE) from pre- to posttraining. Values are mean ± SE. Abbreviations: KR, low-intensity resistance training with vascular restriction group; RT, high-intensity resistance training group; K, vascular restriction only.
* Significant group effect ($P<0.05$), RT > KR and K.

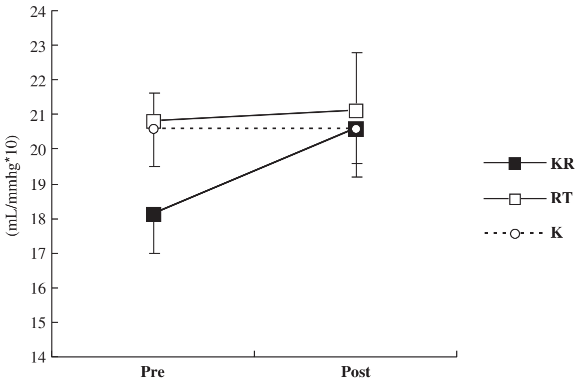

Figure 2. Large artery compliance responses to 3 weeks of training. Values are mean ± SE. Abbreviations: KR, low-intensity resistance training with vascular restriction group; RT, high-intensity resistance training group; K, vascular restriction only. No significant group or time effects ($P>0.05$).

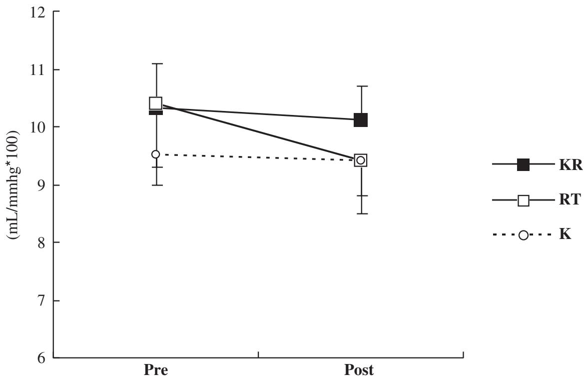

Figure 3. Small artery compliance responses to 3 weeks of training. Values are mean ± SE. Abbreviations: KR, low-intensity resistance training with vascular restriction group; RT, high-intensity resistance training group; K, vascular restriction only. No significant group or time effects ($P>0.05$).

Table 4. Cardiovascular variables

Variables	KR (n=10)		RT (n=10)		K (n=10)	
	Pre	Post	Pre	Post	Pre	Post
SBP, mmHg	124.3 ± 3.9	123.2 ± 1.9	121.9 ± 3.2	118.9 ± 2.9	122.4 ± 3.0	126.5 ± 4.4
DBP, (mmHg	70.7 ± 2.5	71.5 ± 0.9	69.9 ± 2.2	66.8 ± 2.1	68.2 ± 2.1	68.8 ± 2.2
PP, mmHg	53.6 ± 2.3	51.7 ± 1.7	52.0 ± 1.8	52.1 ± 2.0	54.2 ± 2.6	57.7 ± 3.8
RHR, beats/min	60.7 ± 1.2	60.8 ± 1.9	63.1 ± 4.2	60.5 ± 2.8	61.6 ± 2.7	58.8 ± 3.4
SVR, dyne·sec·cm^{-5}	1124.4 ± 41.5	1153.1 ± 36.1	1171.3 ± 67.6	1147.6 ± 39.3	1145.2 ± 50.4	1159.2 ± 58.9
TVI, dyne·sec·cm^{-5}	114.2 ± 4.1	100.2 ± 4.3	95.8 ± 5.5	104.1 ± 5.3	103.4 ± 5.2	107.1 ± 6.8

Values are means ± SE.

Abbreviations: KR, low-intensity resistance training with vascular restriction group; RT, highointensity resistance training group; K, vascular restriction only; SBP, systolic blood pressure; DBP, diastolic blood pressure; PP, pulse pressure; RHR, resting heart rate; SVR, systemic vascular resistance; TVI, total vascular impedance.

No significant group, time or group × time interaction effects (P>0.05).

Table 5. Percent changes in arterial compliance and cardiovascular variables after 3 weeks of training

Variables	Groups		
	KR (n=10)	RT (n=10)	K (n=10)
% Δ LA	17.9 ± 10.3	1.4 ± 6.8	2.1 ± 6.2
% Δ SA	1.4 ± 6.8	-6.41 ± 4.7	0.2 ± 5.5
% Δ SBP	-0.1 ± 3.4	-2.2 ± 2.5	3.2 ± 1.6
% Δ DBP	2.1 ± 3.4	-4.2 ± 2.5	1.1 ± 2.3
% Δ PP	-2.5 ± 3.9	0.7 ± 3.8	6.0 ± 3.3
% Δ RHR	0.9 ± 4.8	-2.1 ± 5.2	-4.4 ± 4.1
% Δ SVR	2.9 ± 1.9	-0.2 ± 4.8	1.2 ± 2.6
% Δ TVI	-10.9 ± 5.6	11.6 ± 8.7	5.7 ± 7.5

Values are means ± SE.

Abbreviations: KR, low-intensity resistance training with vascular restriction group; RT, high-intensity resistance training group; K, vascular restriction only; LA, large artery compliance index; SA, small artery compliance index; SBP, systolic blood pressure; DBP, diastolic blood pressure; PP, pulse pressure; RHR, resting heart rate; SVR, systemic vascular resistance; TVI, total vascular impedance.

No significant differences between groups (P>0.05).

DISCUSSION

This is the first randomized intervention study to investigate the effects of short-term, low-intensity resistance training (i.e., 20% of 1-RM) with vascular restriction, known as KAATSU resistance training, on arterial compliance in healthy young males. We found that the arterial compliance of the large and small arteries was not negatively impacted by the KAATSU low intensity resistance training intervention. However, traditional high intensity resistance training did not decrease arterial compliance in our sample either. Interestingly, the KAATSU resistance training group tended to increase (18%) large artery compliance, whereas the traditional high-intensity resistance training group showed a slight decrease (-6%) in small artery compliance.

Our findings for the traditional high-intensity resistance training intervention agree with those of Rakobowchuk et al. (2005), who reported that 12 weeks of whole-body resistance training did not increase arterial stiffness in young men. Similar results for arterial compliance in older men were documented by Maeda et al. (2006) after 12 weeks of leg resistance training. In contrast, Miyachi et al. (2004) found that 4 months of high-intensity resistance training (80% of 1-RM) reduced central arterial compliance in healthy men. Carotid arterial compliance decreased after 2 months of resistance training, and no further decreases occurred between months 2 and 4 of the study. Additionally, Miyachi et al. (2004) suggested that resistance training negatively affected only central elastic arteries, whose cushioning function dampens fluctuations in blood pressure and flow.

During bouts of high-intensity resistance exercise, large increases in arterial blood pressure can occur, especially if the Valsalva maneuver is performed concomitantly with lifting (Narloch and Brandstater, 1995). Therefore, reduced arterial compliance in resistance-trained men may be an adaptation by the arterial wall to acute intermittent elevations in arterial blood pressure in the cardiothoracic region, resulting in increases in the smooth muscle content and in the load-bearing properties of collagen and elastin (Dobrin, 1995). Another potential physiologic mechanism is that higher sympathetic nervous system activity in resistance-trained men may chronically increase sympathetic adrenergic vasoconstrictor tone (Failla et al., 1999). The discrepancy between our resistance training data and those reported by Miyachi et al. (2004) may be explained in part by differences in duration of training and types of training protocols, as we trained subjects only for 3 weeks (9 total sessions) using 3 lower body resistance exercises (leg press, knee flexion, and knee extension). Also, we used a different technique to assess arterial compliance than the combination of ultrasound imaging and applanation tonomotry used by Miyachi et al. (2004).

As with previous KAATSU studies (Abe et al., 2005; Abe et al., 2006; Fujita et al., 2008; Takarada et al., 2000b; Takarada and Ishii, 2002;), we found that short-term, low-intensity resistance training with vascular restriction elicited improvements in knee extension muscle strength. However, the high-intensity resistance training protocol was effective for improving strength with all the exercises, with the RT group generally exhibiting greater relative increases in strength than the KR group. Although our study had only 9 training sessions, other studies have documented significant increases in muscle strength after 9-12 sessions (Akima et al., 1999; Fujita et al., 2008).

Although the mechanisms related to neuromuscular adaptations with KAATSU training have not been well established, several possible explanations exist. Blood flow restriction may induce neuromuscular adaptations in active muscle, such as alterations in motor unit firing and recruitment patterns, which would result in increased muscle strength (Kawada, 2005). In addition to neural responses, anabolic hormones, such as GH and IGF-1, increase after low-intensity exercise training with blood flow restriction, which may stimulate muscle hypertrophy (Abe et al., 2005; Takarada et al., 2000a). Fujita et al. (2008) reported significant increases in quadriceps muscle cross-sectional area and volume after only 12 KAATSU resistance training sessions. However, the lack of change in leg lean tissue mass in our study suggests that strength increases were primarily the result of neural adaptations to the training protocols.

Further research is needed to determine the effects of KAATSU resistance training on blood vessel function. Acute cardiovascular and hemodynamic responses to KAATSU alone or in combination with low-intensity exercise training have been examined (Iida et al., 2005; Takano et al., 2005a). KAATSU causes venous pooling in the legs, which decreases venous return, reduces cardiac output, and increases total peripheral resistance (Iida et al., 2005). Greater increases in both systolic and diastolic blood pressure occurred with the KAATSU resistance training than with low-intensity exercise training without blood flow restriction (Takano et al., 2005a). Both of those studies utilized protocols with more repetitions and sets than our KAATSU resistance training protocol. Since the focus of our study was to compare the intensities of the protocols, i.e., high-intensity (80% of 1-RM) versus low-intensity (20% of 1-RM) with vascular restriction, we kept the number of repetitions and sets constant.

The short duration of our study is a limitation since it may not have been sufficient to induce adaptations in the arterial wall. It is possible that these vascular responses require a longer training duration for a significant treatment effect to be detected. However, there is evidence to suggest that the elastic properties of the arterial walls are acutely affected by sympathetic nervous system activity (Boutouyrie et al., 1994) and resistance exercise (DeVan et al., 2005).

In conclusion, arterial compliance of the large and small arteries was not affected by either resistance training protocol in our preliminary study. Muscle strength significantly increased in response to both resistance training protocols. However, the traditional high-intensity resistance training protocol tended to cause greater relative improvements in strength than the low-intensity KAATSU resistance training protocol. Our findings indicate that short-duration KAATSU resistance training is not detrimental to arterial compliance in young men. Further investigations are needed to determine the clinical implications of low-intensity resistance training with KAATSU.

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Authors' affiliations

S. J. Kim, **V. D. Sherk**, **M. G. Bemben**, **D. A. Bemben**, Department of Health and Exercise Science, University of Oklahoma, Norman, OK, USA