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Research article

Legs and trunk muscle hypertrophy following walk training with restricted leg muscle blood flow

Mikako Sakamaki [1], Michael G. Bemben [2] and Takashi Abe ✉[1]
[1] Graduate School of Frontier Science, The University of Tokyo, Kashiwa, Chiba, Japan
[2] Department of Health and Exercise Science, The University of Oklahoma, Norman, OK, USA

Abstract
We examined the effect of walk training combined with blood flow restriction (BFR) on the size of blood flow-restricted distal muscles, as well as, on the size of non-restricted muscles in the proximal limb and trunk. Nine men performed walk training with BFR and 8 men performed walk training alone. Training was conducted two times a day, 6 days/wk, for 3 wk using five sets of 2-min bouts (treadmill speed at 50 m/min), with a 1-min rest between bouts. After walk training with BFR, MRI-measured upper (3.8%, $P < 0.05$) and lower leg (3.2%, $P < 0.05$) muscle volume increased significantly, whereas the muscle volume of the gluteus maximus (-0.6%) and iliopsoas (1.8%) and the muscle CSA of the lumber L4-L5 (-1.0) did not change. There was no significant change in muscle volume in the walk training alone. Our results suggest that the combination of leg muscle blood flow restriction with slow walk training elicits hypertrophy only in the distal blood flow restricted leg muscles. Exercise intensity may be too low during BFR walk training to increase muscle mass in the non- blood flow restricted muscles (gluteus maximus and other trunk muscles).

Key words: Vascular occlusion, magnetic resonance imaging, ultrasound.

Introduction

Several studies reported that walk training combined with blood flow restriction (BFR) leads to significant improvements in thigh muscle mass and knee joint strength in both young and elderly men (Abe et al., 2006; 2009; 2010; Ozaki et al., 2011). Although walking involves the muscle groups of the knee and hip joints, our previous studies of BFR walk training have focused solely on thigh muscles distal to pressure cuffs placed on the upper most portion of the proximal thigh. Recently, we observed that following low-intensity (30% of one-repetition maximum [1-RM]) bench press training with BFR, muscle hypertrophy occurred not only in upper arm muscles directly affected by BFR, but also in chest muscles proximal to the area directly affected by BFR (Yasuda et al., 2010; 2011). These results suggest that not only the blood flow–restricted thigh and calf muscles, but also those muscles that are proximal and not directly flow restricted, may demonstrate muscle hypertrophy. We examined the effect of walk training combined with BFR on the size of distal blood flow-restricted muscles, as well as on the size of non-restricted muscles in the proximal limb and trunk.

Methods

Seventeen healthy young men volunteered to participate in the study. Their mean age, standing height, and body weight were 21.2 (±1.9) years, 1.74 (±0.07) m, and 65.8 (±9.6) kg. The subjects were randomly divided into two training groups: walk training with (BFR-walk, n = 9) and without (CON-walk, n = 8) restricted leg muscle blood flow. There was no significant group difference in the physical characteristics of the subjects (Table 1). All subjects led active lives, with 7 of 18 regularly participating in aerobic-type exercise (i.e., jogging, swimming). However, none of the subjects had regularly participated in a resistance exercise program for at least 1 year prior to the start of the study. All subjects were informed of the procedures, risks, and benefits, and signed an informed consent document before participation. The University of Tokyo Ethics Committee for Human Experiments approved the study.

The subjects in both the BFR-walk and CON-walk groups participated in 3 weeks of supervised walk training. Following a warm-up, the subjects performed

Table 1. Effects of walk training with and without blood flow restriction (BFR) on lower body and trunk muscle cross-sectional area (CSA) and muscle volume. Values are means (± SE).

	BFR-walk (n=9)		CON-walk (n=8)	
	Pre	Post	Pre	Post
Age (yr)	21.4 (2.1)		21.1 (1.9)	
Body weight (kg)	63.9 (4.6)	64.3 (4.5)	68.0 (8.9)	67.8 (9.0)
Muscle volume (cm^3)				
Thigh	3456 (135)	3580 (120) *	3667 (248)	3654 (247)
Lower leg	1345 (67)	1392 (80) *	1405 (109)	1398 (109)
Iliopsoas	225 (14)	229 (15) #	228 (11)	229 (11)
Gluteus maximus	722 (29)	717 (27)	783 (60)	771 (55)
Muscle CSA (cm^2)				
L4-L5	102 (4)	101 (4)	113 (6)	110 (7)

Pre, before training; Post, after training; L4-L5, lumber 4-5. * $p < 0.05$, # $p = 0.07$ vs Pre

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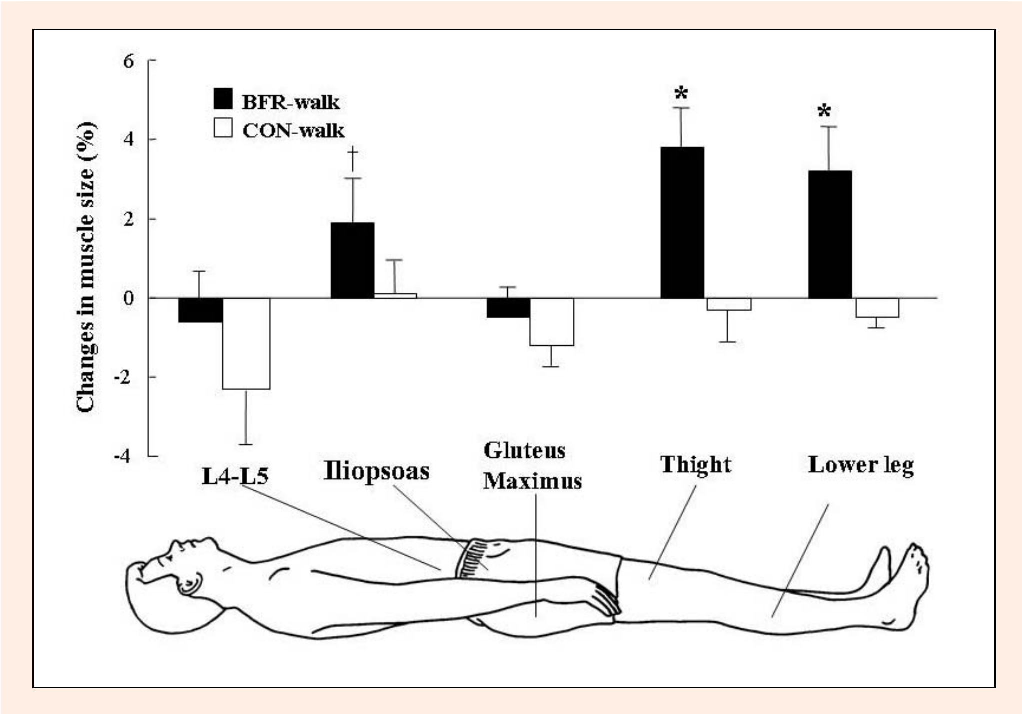

Figure 1. Percent change in muscle cross-sectional area (CSA) and volume following walk training with and without BFR. * $p < 0.05$, † $p = 0.07$, BFR-walk vs. CON-walk.

walking (50 m/minute for five 2-minute bouts, with a 1-minute rest between bouts) on a motor-driven treadmill. The walking speed and duration remained constant throughout the training period. Subjects in the BFR-walk group wore elastic cuffs on the most proximal portion of each leg, and the cuffs were inflated (pressure range from 160 to 230 mmHg) during training sessions, as described previously (Abe et al., 2006).

Magnetic resonance imaging (MRI) images were prepared using a General Electric Signa 1.5 Tesla scanner (Milwaukee, Wisconsin, USA). A T1-weighted, spin-echo, axial plane sequence was performed with a 1500-millisecond repetition time and a 17-millisecond echo time. Subjects rested quietly in the magnet bore in a supine position with their legs extended. With the first cervical vertebra as the point of origin, contiguous transverse images with 1.0-cm slice thickness (0-cm interslice gap) were obtained from the first cervical vertebra to the ankle joint for each subject (Abe et al., 2003). All MRI scans were segmented into four components (skeletal muscle, subcutaneous adipose tissue, bone, and residual tissue) by a highly trained analyst and then traced. For each slice, the cross-sectional area (CSA) of the skeletal muscle tissue was digitized, and the muscle tissue volume (cm^3) per slice was calculated by multiplying muscle tissue area (cm^2) by slice thickness (cm). The muscle volume of individual muscles was defined as the summation of slices. We had previously determined that the coefficient of variation (CV) of this measurement was 1% (Abe et al., 2003). The average value of the right and left sides of the body was used for statistical analysis. This measurement was completed at baseline and 3 days after the final training (post-testing). Results are expressed as means (±SE) for all variables. Baseline differences between the BFR-walk and CON-walk groups and percent changes between baseline and post-testing were evaluated with a one-way ANOVA. Statistical significance was set at $p < 0.05$.

Results

No significant ($p > 0.10$) baseline differences between groups were observed for the physical characteristics and muscle volumes (Table 1). Muscle volume of the thigh and lower leg increased ($p < 0.05$) by 3.8%, 3.2%, respectively, in the BFR-walk group following training (Table 1 & Figure 1). The percent change in thigh muscle volume tended to correlate with the percent change in lower leg muscle volume ($r = 0.60$, $p = 0.09$) in the BFR-walk group. However, gluteus maximus muscle volume and lumbar L4-L5 muscle CSA did not change in the BFR-walk group. Iliopsoas muscle volume tended to increase ($p = 0.07$) after training, although the change was not statistically significant. There was no significant change ($p > 0.05$) in each muscle volume in the CON-walk group (Table 1 & Figure 1).

Discussion

The results of the current study confirm the previous findings (Abe et al., 2006; 2009; 2010; Ozaki et al., 2011) in that there was a significant increase in muscle volume of the thigh (3.8%) and lower leg (3.2%) after 3 weeks of walk training in the BFR group, whereas no change in muscle volume was observed in the control group. On the contrary, no significant change in muscle volume of the gluteus maximus or muscle CSA at L4-L5 was observed in either group. Those changes in muscle size were specific to limb muscles where blood flow was restricted, whereas no change was observed in non-restricted trunk muscles. On the other hand, we have demonstrated that low-intensity (30% 1-RM) bench press training combined with BFR resulted in muscular hypertrophy of the chest muscles (Yasuda et al., 2010; 2011). Similarly, 20% 1-RM resistance exercise using a squat machine and leg curl in combination with BFR resulted in muscular hypertrophy of the gluteus maximus (Abe et al., 2005). These results suggest that the anabolic effect of such exercise is not limited locally but can be transferred to other muscles that are not directly affected by blood flow restriction. As such, Madarame et al. (2008) demonstrated a significant increase in non-restricted elbow flexor muscles when subjects performed 10 weeks of unilateral arm curl exercise (50% 1-RM) without BFR, followed by leg knee extension and knee flexion exercise with BFR. Therefore, the original exercise intensity plus BFR-mediated increase in muscle activation (Yasuda et al., 2010) and other systemic factors, such as circulating anabolic hormones and/or acute muscle tissue swelling (Takarada et al., 2000; Abe et al., 2005; Yasuda et al., 2011), may contribute to the muscle hypertrophy seen in muscles that are not flow restricted during exercise.

Conclusion

Our results suggest that the combination of leg muscle blood flow restriction with slow walk training elicits muscle hypertrophy only in the distal, flow restricted leg muscles. The exercise intensity may be too low during BFR walk training to cause muscle hypertrophy in the non- blood flow restricted gluteus maximus and other trunk muscles.

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Key points

- Previous studies of blood flow restricted walk training have focused solely on thigh muscles distal to pressure cuffs placed on the upper most portion of the proximal thigh.
- In the current study, both proximal and distal muscles were evaluated following the combination of walk training with leg blood flow restriction (BFR). Muscle hypertrophy only occurred in the thigh and lower leg, which were the blood flow restricted muscles examined.
- No significant change was observed in the non-restricted trunk muscles following 3 weeks of twice-daily BFR walk training.

AUTHORS BIOGRAPHY

Mikako SAKAMAKI
Employment
University of Tokyo, Graduate School of Frontier Sciences, Japan
Degree
PhD
Research interest
Exercise physiology, Resistance training for women.
E-mail: mikako@h.k.u-tokyo.ac.jp

Michael G. BEMBEN
Employment
Professor, Department of Health and Exercise Science, Univer
of Oklahoma, USA
Degree
PhD
Research interest
Exercise physiology, Aging and neuromuscular adaptation
E-mail: mgbemben@ou.edu

Takashi ABE
Employment
Professor, University of Tokyo, Graduate School of Frontier Sciences, Japan
Degree
PhD
Research interest
Exercise physiology, Aging and skeletal muscle plasticity.
E-mail: t12abe@gmail.com

✉ **Takashi Abe, PhD**
Department of Human and Engineered Environmental Studies, Graduate School of Frontier Science, The University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba 277-8563, Japan