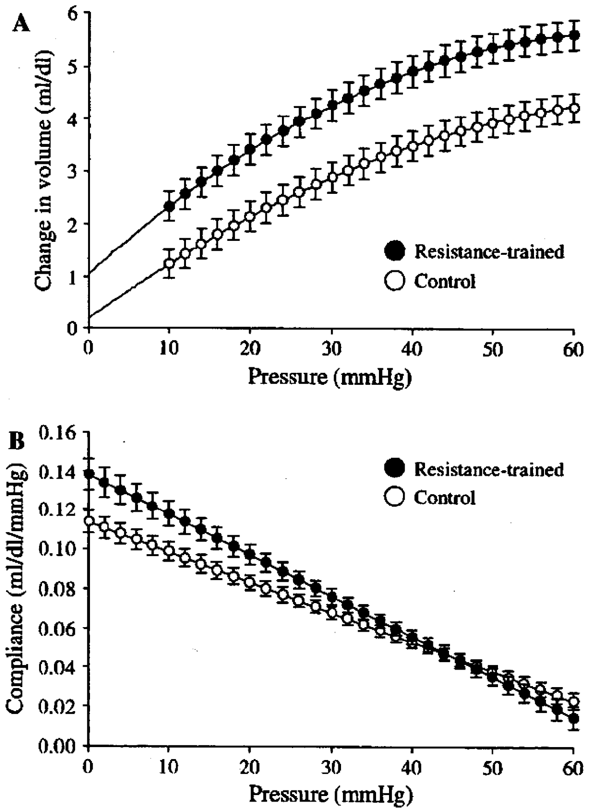

Fig. 1 Pressure–volume (a) and pressure–compliance relations (b) in the resistance-trained men and age-matched controls. Values are mean ± SEM

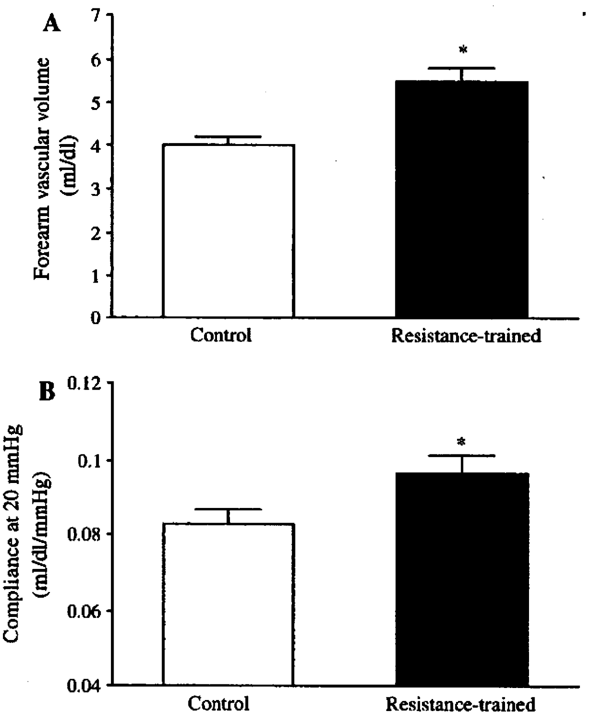

Fig. 2 Forearm venous volume (a) and forearm venous compliance at 20 mmHg cuff pressure (b) in the resistance-trained men and age-matched controls. Values are mean ± SEM

Discussion

This study was performed to investigate the association between habitual resistance training and venous compliance. We found that the resistance-trained group showed greater venous compliance in the forearm compared with the age-matched controls, and that the forearm venous compliance was associated with forearm venous volume (i.e., capacitance), but not with forearm muscle mass. To our knowledge, this is the first study designed to assess the association between resistance training and venous compliance. The present findings may expand our understanding of the alterations in vascular function caused by habitual exercise.

Reason for determining venous compliance in the forearm

We determined upper limb venous compliance in the resistance-trained group, although previous studies have emphasized the importance of lower limb blood volume in relation to orthostatic stress, and indirectly assessed the effects of resistance training on venous compliance using lower body negative pressure (Lightfoot et al. 1994; Smith and Raven 1986). As the resistance-trained men in the present study performed whole-body strength training, it was presumed that their forearms would have generated tonic force in most resistance exercises, including lower limb exercise. Moreover, the lower limbs were exercised daily through light to moderate physical activity, such as walking or jogging (i.e., aerobic exercise), but the upper limbs were not. Accordingly, we assumed that greater

Table 2 Pressure–volume regression parameters

	ΔLimb volume $= \beta_0 + \beta_1$(cuff pressure) $+ \beta_2$(cuff pressure)^2
Control	ΔLimb volume = 0.172 ± 0.273 + 0.113 ± 0.006(cuff pressure) − 0.00076 ± 0.00007(cuff pressure)^2
Resistance-trained	ΔLimb volume = 1.048 ± 0.285* + 0.138 ± 0.008*(cuff pressure) − 0.00103 ± 0.00010*(cuff pressure)^2

Data are mean ± SEM

* Significant at $P < 0.05$ versus control

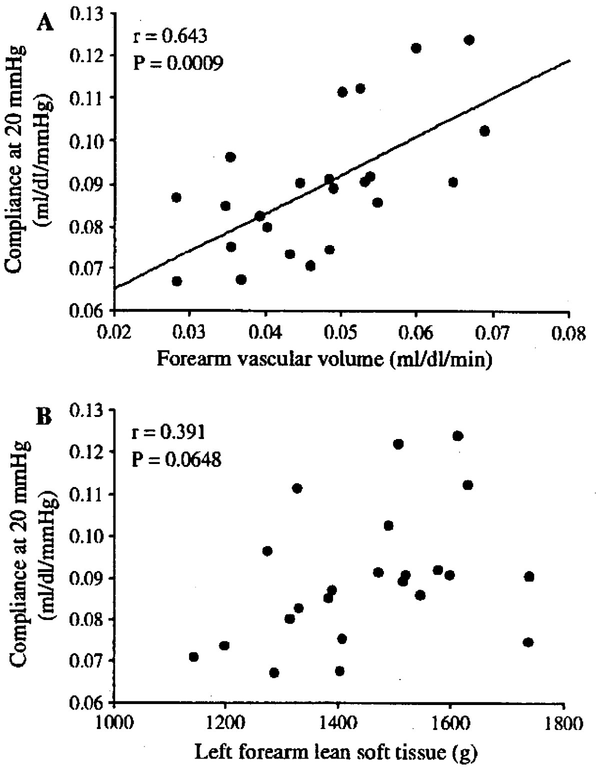

Fig. 3 Relations between forearm venous volume (**a**) or forearm lean soft tissue (**b**) and forearm venous compliance at 20 mmHg cuff pressure in all subjects

effects of resistance training would be seen in the upper limb compared with the lower limbs, and therefore measured forearm venous compliance.

Physiological and clinical significance

Venous compliance and capacitance of the extremities are major determinants of the amount of blood that may be translocated to the central region (Rowell 1993). In addition, greater compliance and capacitance mean that the venous reflux can be largely pooled in the extremities. Therefore, the greater venous compliance and capacitance in the resistance-trained group promote the drainage of blood from the limbs during muscular contraction, which may contribute to the removal of metabolites and fatigue factors. This speculation should be verified in future studies. Furthermore, venous compliance is reduced with advancing age (Monahan et al. 2001), which may be one of the risk factors for varicose veins and deep vein thrombosis. Indeed, previous studies have indicated that aging induces an increase in the incidence of venous thromboembolism (Glynn et al. 2007; Glynn and Rosner 2005) and that venous compliance was related to blood clot length or stenosis (Turner et al. 2000). On the other hand, the intrinsic function of venous compliance is to accept blood. Greater venous compliance may prevent ischemia by blood clots, because of the greater vasodilation at a given pressure. Based on these viewpoints, habitual resistance training may play a role of countermeasure respect to venous thrombus. Although the present study did not investigate the effects of aging, the greater venous compliance in resistance-trained men may be associated with attenuation of these risks.

As it is well known that the derivative of compliance ($\Delta V/\Delta P$) is affected by basal volume, we speculated that venous capacitance (volume) may be one of the determinants of venous compliance. This hypothesis was supported by stepwise multiple regression, which revealed that among all parameters, forearm venous volume was the only independent correlate of forearm venous compliance ($\beta = 0.627$). This suggests that venous capacitance is a determinant of venous compliance.

Delaney et al. (2008) reported that venous capacitance is reduced in hypertensive young men compared with normotensive individuals, but that there is no difference in venous compliance. They speculated that these findings may be due to increased smooth muscle tone. In the present study, although blood pressure in the resistance-trained group was significantly higher than that in the control group, both venous capacitance and compliance were greater in the resistance-trained men. These results suggest that there are essential differences in the morphological and functional adaptations in the veins of subjects who undertake habitual resistance training and subjects with chronic hypertension.

Mechanisms

Although the mechanism involved in the ability of resistance training to enhance forearm venous compliance has not been determined, we speculate on the mechanism by which forearm venous compliance is greater in the resistance-trained group than in the control group. Both structural and regulatory factors may be associated with the difference in venous compliance between the resistance-trained men and those in the control group. First, the structural factor indicating venous capacitance was markedly larger in the resistance-trained group compared with the control group; this was strongly associated with venous compliance in the present study. Several previous studies indicated that both resistance and endurance training induce structural changes in the arteries and veins of trained limbs, i.e., vascular remodelling and vasculogenesis (Dinenno et al. 2001; Galetta et al. 2006; Miyachi et al. 2005; Miyachi et al. 2001; Zoeller et al. 2009). Moreover, we speculated that alterations in the composition of the venous wall, such as changes in the elastin-to-collagen ratio and collagen cross-linking, may explain the higher forearm venous compliance found in association with habitual resistance training (Bouissou et al. 1991).

Second, similar to studies involving endurance training, functional factors, i.e., autonomic nervous control and endothelial functions, may be associated with greater venous compliance in resistance-trained men. However, sympathetic nerve activity was reported to be increased (Pratley et al. 1994) or to remain unchanged by resistance training (Carter et al. 2003). Furthermore, in contrast to studies involving endurance training, flow-mediated dilation did not increase with resistance training (Rakobowchuk et al. 2005b). Taken together, these findings do not support the hypothesis that changes in sympathetic nerve activity and endothelial function contributed to the greater venous compliance in the resistance-trained group in the present study. However, because sympathoexcitation induced during lower body negative pressure restrained limb venous compliance (Monahan and Ray 2004), the relationship between sympathetic outflow and venous compliance should be investigated further.

Third, previous studies suggested that muscle mass surrounding the deep calf veins plays a primary role, such as the negative relationship observed between muscle mass and venous compliance in the calf (Convertino et al. 1988; Monahan et al. 2001). However, we found a positive relationship between muscle mass and venous compliance in the forearm, although it was not significant ($r = 0.391$, $P = 0.0648$), which was inconsistent with previous results. The discrepancies between the results of the present and previous studies may be explained by differences in region examined, such as the calf and forearm. Due to the lower intramuscular pressure in the forearm compared to the calf, muscle mass in the forearm may not markedly affect venous compliance. Therefore, we speculate that in the upper limb, greater venous compliance with resistance training may be determined by increased vascular volume induced by muscular hypertrophy. Clearly, further studies are warranted to determine the physiological mechanisms underlying the effects of resistance exercise on venous haemodynamics.

Study limitations

The reader should be aware of several limitations associated with the present study. First, we found that resistance-trained men have 17% greater venous compliance than age-matched sedentary controls. However, although there have been a few studies regarding forearm venous compliance (Halliwill et al. 1999; Young et al. 2006), there have been no reports regarding the associations between forearm venous compliance and venous disease, blood translocation or orthostatic challenge. Therefore, it is not yet clear whether this difference in magnitude of compliance between the two groups is clinically and physiologically significant. Second, although we found greater forearm venous compliance in resistance-trained men than age-matched sedentary controls, we did not determine calf venous compliance. Due to the tolerance response to orthostatic stress in resistance-trained men (Smith and Raven 1986) and the negative relationship between compliance and muscle mass in the lower limbs (Convertino et al. 1988), we cannot exclude the possibility that decreased venous compliance in the lower limb may be induced by resistance training. Therefore, it is possible that alterations in venous compliance with resistance training are affected by difference between the upper and lower limbs, and this should be confirmed in further studies. Third, due to the tolerance response to lower body negative pressure in resistance-trained men (Smith and Raven 1986), resistance training is a countermeasure for preventing hypotension, syncope and collapse (Brilla et al. 1998). Although our results indicated greater forearm venous compliance in resistance-trained men, this adaptation with resistance training may not markedly affect hypotension, syncope and collapse in resistance-trained men because of the smaller vascular volume in the upper limbs in comparison to the lower limbs. Fourth, habitual resistance training may induce arterial stiffening (Kawano et al. 2006; Kawano et al. 2008; Miyachi et al. 2003, 2004). If resistance-trained men in the present study had reduced arterial compliance, alterations in venous compliance with resistance training are in contrast to arterial adaptation. However, as we did not determine arterial stiffness in the present study, further studies are required to investigate the relationship between arterial and venous compliance in resistance-trained men.

Conclusions

Our results suggest that (1) resistance-trained men have greater forearm venous compliance than age-matched sedentary controls, and (2) higher forearm venous compliance in the resistance-trained men may be explained by greater forearm venous capacitance. These findings of the present cross-sectional study must be confirmed prospectively in a future resistance exercise intervention study.

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Effects of 10 Weeks Walk Training With Leg Blood Flow Reduction on Carotid Arterial Compliance and Muscle Size in the Elderly Adults

Hayao Ozaki, MS[1], Motohiko Miyachi, PhD[2], Toshiaki Nakajima, MD, PhD[3], and Takashi Abe, PhD[1]

Abstract

High-intensity resistance training increases muscle size, but reduces arterial compliance. Muscular blood flow reduction (BFR) during low-intensity training has been shown to elicit muscle hypertrophy. However, the effect on arterial compliance is unknown. We examined the effects of walk training with BFR on carotid arterial compliance and muscle size in the elderly adults. Both BFR-walk training (BFR-W, n = 13, 66 ± 1 year) and control-walk training (CON-W, n = 10, 68 ± 1 year) groups performed 20 minutes treadmill walking at an exercise intensity of 45% of heart rate reserve, 4 days/week for 10 weeks. The BFR-W group wore pressure cuffs on both legs during training. Maximum knee joint strength (~ 15%) and MRI-measured thigh muscle cross-sectional area (3%) increased in the BFR-W, but not in the CON-W. Carotid arterial compliance improved in both BFR-W (50%) and CON-W (59%) groups. Walk training with blood flow reduction can improve thigh muscle size/strength as well as carotid arterial compliance, unlike high-intensity training, in the elderly.

Keywords

aging, exercise, occlusion, stiffness

Introduction

Age-related skeletal muscle loss (Sarcopenia) inhibits functional mobility and increases the risk for metabolic-related diseases such as diabetes, osteoporosis, and cardiovascular disease.[1,2] Traditional high-intensity resistance training can induce skeletal muscle hypertrophy and improve insulin sensitivity and glycemic control in middle-aged and older participants.[3-5] It is also thought that high-intensity resistance training may prevent or reverse sarcopenia-related issues such as the risk of falls in older people. However, previous studies[6,7] have indicated that high-intensity resistance training reduces central arterial compliance in young and middle-aged subjects. Reductions in arterial compliance are associated with high rates of mortality in patients with end-stage renal failure and essential hypertension. Additionally, low arterial compliance contributes to elevations in systolic blood pressure and coronary heart disease and reductions in arterial baroreflex sensitivity.[8,9] Although, the traditional resistance training is an effective tool to improve sarcopenia or osteoporosis, it may also have deleterious effects on central arterial compliance.

Muscular blood flow restriction (BFR) during resistance training has been shown to elicit similar muscle hypertrophy as traditional high-intensity resistance training but with much lower training intensity.[10] An intensity as low as walking when combined with BFR can lead to significant improvements in knee joint strength and leg muscle hypertrophy.[11,12] Improvements in muscle size and function using a single mode of BFR walk training may become a training method for the broader population, including the frail and older people. However, the effect of low-intensity walk training with BFR on carotid arterial compliance has not yet been explored. Thus, the purpose of this study was to investigate the effects of BFR walk training on carotid arterial compliance and muscle size/function in older people.

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Methods

Participants

A total of 23 sedentary men and women, aged 57 to 76 years, volunteered to participate in the current study. The participants were recruited through printed advertisement and by word of mouth and had not participated in a regular exercise programme for at least the previous 3 years. All participants were normotensive (brachial blood pressure $\leq$140/90 mm Hg) and free of overt chronic diseases as assessed by medical history, physical examination, and complete blood chemistry and hematological evaluation. Candidates who had smoked in the previous 4 years and who were taking medications or female hormone supplements were excluded. All participants were informed of the methods, procedures and risks, and signed an informed consent document before participation. The study was conducted according to the Declaration of Helsinki and was approved by the Ethics Committee for Human Experiments of the University of Tokyo, Japan. Participants were subsequently divided into either walk training with BFR group (BFR-W, 3 men and 10 women; $n = 13$) or walk training without BFR group (CON-W, 2 men and 8 women; $n = 10$).

Training Protocol

The participants in both the BFR-W and CON-W groups performed 20-minute treadmill walking at an exercise intensity of predetermined 45% of heart rate reserve (HRR). One week before the start of the training study, walking speed and grade were adjusted for each participant during submaximal walking test and the exercise load condition of each participant was determined and remained constant throughout the training period. Age predicted maximal heart rate (220 minus age) was used to determine the HRR for each participant. The training session was conducted 4 days per week for 10 weeks.

Blood Flow Restriction and Its Safety

Participants in the BFR-W group wore elastic cuffs (5 cm wide; Kaatsu-Master system, Sato Sports Plaza, Tokyo, Japan) on the most proximal portion of both legs during training session. Prior to the training session, the participants were seated on a chair and the upper thigh-mounted cuff was inflated at 120 mm Hg for 30 seconds, and the air pressure was released. The air pressure was increased by 20 mm Hg, held for 30 seconds, and then released for 10 seconds before the next occlusive stimulation was performed. This process was repeated until a final occlusion pressure for each training day was reached. On the first day of training, the final cuff air pressure (training cuff pressure) was 140 mm Hg. As participants adapted to the occlusive stimulus during early phase of the training, the training pressure was increased by 10 mm Hg each week until a final cuff pressure of approximately 200 mm Hg was reached. Even though walking speed remained constant throughout the study, progressive overload of both skeletal muscle and central circulation were still achieved by the gradual increases in restriction pressure that occurred at the beginning of each training week. A training cuff pressure was selected based on a review of the data in older participants.[12] Blood flow to the leg muscles was reduced during each training session for each participant and the cuff air pressure was released immediately upon completion of the session. Our previous study demonstrated that low-intensity exercise combined with BFR has no impact on blood clotting function as assessed by the changes in fibrin D-dimer and fibrin degradation products after exercise.[13] Furthermore, unlike complete blood flow occlusion and reperfusion, moderate restriction of blood flow while performing low-intensity exercise does not affect production of reactive oxygen species, as assessed by the plasma lipid peroxide,[14] blood glutathione status, and plasma protein carbonyls.[15] These findings together support the notion that low-intensity BFR training does not pose any immediate health concerns among older population.

Measurements of Carotid Arterial Compliance

Brachial blood pressure was measured using a semiautomated osillometric device (DINAMAP Procare Monitor, GE Medical System, Milwaukee, Wisconsin) after participants had rested in the supine position at least 15 minutes in quiet. Oscillometric blood pressure measurements have been found to be valid.[16] After the blood pressure measurements, carotid arterial compliance was measured as previously described.[7] Properties of the common carotid artery were measured using an ultrasound apparatus with a 5-MHz linear transducer (SSD-3000, Aloka Co Ltd, Tokyo, Japan). A longitudinal image of cephalic portion of the common carotid artery was acquired 1 to 2 cm distal to the carotid bulb. The carotid artery diameter was determined from the ultrasound images. All image analyses were performed by the same investigator, who was blinded to the group assignments. The pressure waveforms and amplitudes were obtained from the common carotid artery with pencil-type probe incorporating a high-fidelity strain-gage transducer (SPT-301, Millar Instruments Inc., Houston, Texas). Because baseline levels of blood pressure are subjected to hold-down force, the pressure signal obtained by tonometry was calibrated by equating the carotid mean arterial and diastolic blood pressure to the brachial artery value. Carotid arterial compliance was calculated using the equations $([D_1 - D_0]/ D_0)/(2[P_1\text{-}P_0])*\pi*(D_0)^2$, where D_1 and D_0 are maximal and minimum diameters, and P_1 and P_0 are carotid systolic and diastolic blood pressure. The coefficient of variation (CV) for this measurement in our laboratory was 1.5%.

Measurements of Muscle Size and Strength

Magnetic resonance images (MRI) were prepared using a General Electric Yokokawa Signa 0.3-T scanner (Milwaukee, Wisconsin). A T1-weighted, spin-echo, axial plane sequence was performed with a 520-ms repetition time and a 20-ms echo time. The participants rested quietly in the magnet bore in a supine position with their legs extended. Contiguous transverse images with 1.0 cm slice thickness (0 cm interslice gap) were obtained from the knee joints to the upper portion of the thigh

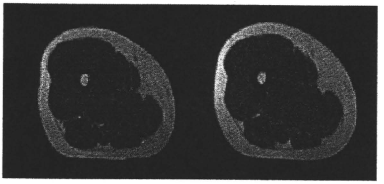

Figure 1. Typical magnetic resonance images of the right side of mid-thigh taken before (PRE) and after (POST) the 10-weeks walk training with blood flow reduction (participant NM).

(Figure 1). All MRI data were transferred to a personal computer for analysis using specially designed image analysis software (Tomo Vision Inc., Montreal, Canada). An average value of the right sides of the body was used. We have previously determined that the CV of this measurement was 2.1%.[11]

Maximum voluntary isokinetic strength of the knee extensors and flexors were determined using a Biodex System-3 dynamometer. Participants were carefully familiarized with the testing procedures of voluntary force production of the thigh muscles during several submaximal and maximal performances about 1 week before testing. The participants were seated on a chair with their hip joint angle positioned at 85°. The center of rotation of the knee joint was visually aligned with the axis of the lever arm of the dynamometer and the ankle of the right leg was firmly attached to the lever arm of the dynamometer with a strap. Several warm-up contractions were performed prior to testing. Participants were then instructed to perform maximal isokinetic knee extensions and flexions, between 0° and 90° range of motion for the knee at 30 deg/sec. A knee-joint angle of 0° corresponded to full extension of the knee.

Statistical Analyses

Results are expressed as means and standard error (SE) for all variables. Statistical analyses were performed by a 2-way analysis of variance (ANOVA) with repeated measures (Group [BFR-W and CON-W] × time (pretesting and posttesting)]. Post hoc testing was performed by a paired *t* test. Baseline differences and percentage changes between BFR-W and CON-W were evaluated with 1-way ANOVA. Statistical significance was set at $P < .05$.

Results

At the start of the experiment, there were no significant differences between BFR-W and CON-W groups for age, body mass index, mid-thigh muscle cross-sectional area (CSA), and knee extension and flexion strength (Table 1). Also, resting blood pressure, heart rate, and carotid arterial compliance was similar between BFR-W and CON-W groups (Table 2).

After 10 weeks of walk training, maximum isokinetic knee extension and flexion torques increased ($P < .01$) in the BFR-W group but not in the CON-W (Table 1). Thigh muscle CSA was also increased ($P < .01$) in the BFR-W group but not in the CON-W (Table 1, Figure 1). Percentage changes in knee extension and flexion strength and thigh muscle CSA were higher in BFR-W (8.7%, 15.0%, and 3.2%, respectively) than in the CON-W (2.7%, −0.3%, and −0.2%).

Carotid arterial compliance improved ($P < .01$) in both CON-W and BFR-W groups. Increase in arterial compliance was similar between 2 walk training groups (CON-W, 59% and BFR-W, 50%). There was no significant change in carotid and brachial blood pressure at rest for either group before and after the training (Table 2).

Discussion

The major findings of the current study were that knee joint strength and thigh muscle size increased following 10 weeks of walk training combined with BFR in the elderly people. In addition, carotid arterial compliance improved by BFR walk training, suggesting that the concurrent improvements in arterial compliance and muscle hypertrophy can be achieved with walk training with BFR. Arterial blood pressure did not change due to training, thus the alterations in arterial compliance were primarily a result of changes in arterial distension.

Previous cross-sectional studies found that regular aerobic exercise is efficacious in improving arterial compliance in middle-aged and older adults.[17,18] Conversely, individuals who performed high-intensity resistance training on a regular basis demonstrated lower levels of carotid arterial compliance than their sedentary peers.[6,19] Consistent with the cross-sectional findings, 4 months of high-intensity resistance training induced approximately 20% reductions in carotid arterial compliance.[7] Traditional resistance training is an effective tool in reversing sarcopenia and/or osteoporosis. However, this type of training has deleterious effects on central arterial compliance. In the current study, our results demonstrated that BFR walk training improves not only arterial compliance but also thigh muscle hypertrophy. This method therefore might be a useful way to improve both muscle size/function and arterial compliance with a single type of training.

The small sample size that was used in this study was similar to previous studies using blood flow restriction and was adequate to demonstrate statistical significance with the outcome variables. We would anticipate that the results would be very similar for a larger group of healthy older adults but further research is needed to determine the efficacy of this method for other populations that may have clinical limitations such as diabetes and hypertension.

Aerobic-type exercise training has consistently demonstrated improvement in central arterial compliance. In the current study, arterial compliance increased 50% and 59%, respectively, in the walk training (45% of HRR) with or

Table 1. Changes in Anthropometric Variables, Skeletal Muscle Size, and Strength Following 10-Weeks Walk Training With (BFR-W) and Without (CON-W) Blood Flow Reduction[a]

	BFR-W			CON-W		
	PRE	POST	%	PRE	POST	%
Anthropometric variables						
Age (yr)	66 (1)			68 (1)		
Standing height (m)	1.56 (0.01)			1.54 (0.02)		
Body mass (kg)	55.9 (1.5)	55.3 (1.4)[b]	−0.9	55.9 (2.8)	55.6 (2.8)[b]	−0.7
BMI (kg/m²)	23.0 (0.7)	22.8 (0.7)[c]	−0.9	23.5 (1.0)	23.3 (1.0)[c]	−0.7
Thigh muscle CSA and strength						
CSA (cm²)	104 (5)	107 (5)[c]	3.2[d]	100 (5)	99 (5)	−0.2
Knee extension (Nm)	110 (5)	120 (6)[c]	8.7	104 (6)	108 (9)	2.7
Knee flexion (Nm)	55 (4)	62 (3)[c]	15.0[d]	50 (5)	50 (6)	−0.3

Abbreviations: BMI, body mass index; CSA, cross sectional area.
[a] Data are mean ± SE.
[b] $P < .05$, PRE versus POST.
[c] $P < .01$.
[d] $P < .01$, BFR-W versus CON-W.

Table 2. Changes in Carotid Arterial Compliance, Resting Blood Pressure and Heart Rate Following 10-Weeks Walk Training With (BFR-W) and Without (CON-W) Blood Flow Reduction[a]

	BFR-W		CON-W	
	PRE	POST	PRE	POST
Arterial compliance (mm²/mm Hg)	0.084 (0.012)	0.118 (0.016)[b]	0.079 (0.009)	0.114 (0.010)[b]
Resting blood pressure and HR				
cSBP (mm Hg)	108 (6)	111 (7)	111 (5)	106 (7)
bSBP (mm Hg)	117 (5)	119 (5)	117 (5)	115 (5)
bDBP (mm Hg)	67 (3)	68 (3)	64 (2)	62 (3)
bMAP (mm Hg)	85 (4)	87 (5)	85 (3)	81 (4)
HR (bpm)	67 (2)	62 (3)	64 (2)	63 (3)

Abbreviations: bDBP, brachial diastolic blood pressure; bMAP, brachial mean arterial pressure; bSBP, brachial systolic blood pressure; cSBP, carotid systolic blood pressure; HR, heart rate.
[a] Data are mean ± SE.
[b] $P < .01$, PRE versus POST.

without BFR groups and these data are in line with previously reported aerobic exercise training studies. The mean levels of arterial compliance in the endurance-trained middle-aged and older men are 28% to 40% higher than in their age-matched sedentary peers.[18] Similarly, 25% to 30% reductions of carotid arterial stiffness[20] and beta-stiffness index[21] were observed following 12 weeks of moderate intensity (40% of HRR) or vigorous intensity (70% of HRR) aerobic exercise training. This is the first study to demonstrate chronic BFR walk training-induced improvement in arterial compliance. However, a recent acute exercise study[22] reported that an index of systemic arterial compliance (stroke volume/pulse pressure ratio, calculated from the finger blood pressure waveform) and popliteal arterial endothelial function (via flow-mediated vasodilation) were decreased after an acute bout of slow-walking exercise combined with leg BFR. It was anticipated that the results of chronic adaptation of resting arterial properties would be different than the acute responses to BFR exercise. To date, there has been no systematic study on the interactions of altering exercise intensity or duration of BFR during walking and the fitness levels of the participants. Nevertheless, because central arterial compliance is a more important risk factor for mortality associated with cardiovascular disease than peripheral arterial compliance, any central cardiovascular adaptation from chronic training would be a better research outcome.

The reasons for BFR walk training-induced improvement in arterial compliance are not clear, but there are several possible physiological mechanisms to explain the change in arterial compliance. Previous studies[6,7] indicated that the major contributor of resistance training-induced arterial stiffening is the elevation of blood pressure (250-320 mm Hg) during each bout of high-intensity resistance training.[23] These acute intermittent elevations in arterial blood pressure during resistance exercise may have altered the arterial structure and/or the arterial load-bearing properties of collagen and elastin,[24] thereby causing arterial stiffening. Elevations of arterial blood pressure during moderate intensity aerobic exercise bout[25] as well as walking with BFR[26] are lower compared with that during high-intensity resistance exercise. After aerobic exercise training in rats, total aortic elastin content increased whereas calcium content of elastin decreased.[27] Furthermore, collagen cross-linking in the left ventricle of aerobic-trained rats was lower than that of sedentary counterparts.[28] These findings suggest that a partial reversal of age-related changes in the elastin and collagen structure and content of the arterial wall may contribute to the beneficial effects of BFR walk training on arterial compliance.

Our findings showed that significant hypertrophic response occurred in the thigh muscle for the BFR-W group, although there was no change in the CON-W group. This finding is consistent with our previous investigations in young[11] and older[12] participants. Only 2 studies have attempted to elucidate the cellular and molecular mechanisms of adaptation in skeletal muscle in response to low-intensity BFR exercise training. Fujita et al (2007) demonstrated that a single bout of 20% of 1-RM intensity knee extension exercise with BFR increased both vastus lateralis muscle protein synthesis and the Akt/mammalian target of the rapamycin signaling pathway in young men, although the rate of muscle protein breakdown was not measured. Recently, low-intensity BFR exercise-induced increase in muscle protein synthesis was also confirmed in older men.[30] These anabolic responses may contribute significantly to BFR walk training-induced muscle hypertrophy.

In conclusion, slow walk training with BFR can produce thigh muscle hypertrophy and increased knee joint strength in the elderly people. Unlike high-intensity resistance training, however, carotid arterial compliance improved following 10 weeks of BFR walk training.

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The Relation between Daily Step Counts and Medical Costs in Japanese : Ecological Study

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Abstract

The link between daily step counts and medical costs was evaluated in Japanese by ecological study. We used data for mean value of medical costs in each prefecture by Ministry and Health,Labour Welfare, Japan and data for mean value of daily step counts in each prefecture by Cabinet Office, Government of Japan. Daily step counts in men was significantly correlated with medical costs ($r=-0.342$, $p=0.0185$). However, daily step counts in women was not correlated with medical costs ($r=0.019$, $p=0.9007$). This ecological study suggests that higher daily step counts may induce lower medical costs in Japanese men.

Key words: medical costs, daily step counts, ecological study

I. Introduction

The health benefits of regular physical activity and exercise are widely accepted and are becoming better in Japan[1]. For example, only 28.6% of men and 24.6% of women engage in physical activity in Japan[1]. Health Japan 21, a national 10-year campaign to set goals to promote the general health of Japanese, recommends increasing the proportion of the Japanese population engaging in regular physical activity to 39% and 35% among men and women by 2010.

Sedentary lifestyle may increase medical costs and encouraging physical activity may reduce medical costs and improve people's health status[2]. However, little is known about the actual impact of the medical costs saved by physical activity in Japanese.Therefore, we preliminary examined the relation between medical costs and daily step counts in Japanese by using ecological study.

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II. Methods

We used data for mean value of medical costs (per person and per 1-year), which was calculated by National Health Insurance in each 47 prefecture and was officially announced by Ministry and Health, Labour Welfare,Japan (http://www.mhlw.go.jp/topics/bukyoku/hoken/iryomap/06/dl/kokuho.pdf, accessed on May 29, 2009). We also used data for mean value of daily step counts in each 47 prefecture by Cabinet Office, Government of Japan(http://www 8.cao.go.jp/syokuiku/data/whitepaper/2008/pdf_file/shiryo. pdf, accessed on May 29, 2009). Pearson's correlation coefficients were calculated and used to test the significance of the linear relationship among continuous variables.

III. Results

Mean value of daily step counts of men (8371.5 steps per day) in Kanagawa prefecture and of women (7777.5 steps per day) in Kouchi prefecture was highest among 47 prefectures.Mean value of medical costs in Kouchi prefecture was highest among 47 prefectures. We investigated the relationship between medical costs and daily step counts (**Figure**). Daily step counts in men was significantly correlated with medical costs ($r=-0.342, p=0.0185$). However, daily step counts in women was not correlated with medical costs ($r=0.019, p=0.9007$).

IV. Discussion

Daily walking reduces visceral fat area, improves insulin resistance and lowers blood pressure[3,4]. However, there are few reports to evaluate the link between medical costs and exercise in Japanese. Kuriyama have reported that medical costs based on National Health Insurance in subjects without walking habits (under the level of one hour per day) were higher than those in subjects with walking habits with 7-years follow up[5]. Tsuji et al also reported that medical costs significantly reduced with longer time spent walking with 4-year follow up[6]. In that reports, the question on the walking time for each subject was worded as 'How long do you walk a day, on average?', and the subjects were asked to choose one out of three options: ≦30 minutes, 30 minutes-1 hour, and≧1 hour. In this study, daily step counts in men were negatively correlated with medical costs in each prefecture, Japan. This suggests that increasing daily step counts may associate with lowering medical costs in Japan.

Potential limitations still remain in this study. First, this study was ecological study not longitudinal investigation study. The link between daily step counts and medical costs, which was noted in this study, may not apply for the link among individuals. Second, the health insurance system is almost classified into two different categories in Japan. One is the insurance system for employees and their dependents, and the other is a system of community-based health insurance called National Health Insurance, which covers farmers, the self-employed and pensioners. Medical costs in this study were based on only National Health Insurance association.Third, the link between medical costs and daily step counts in women was not noted. Daily step counts were calculated by selected subjects in each prefecture, and the sample size might affect the association between daily step counts and medical costs.In Kouchi prefecture, mean daily step counts of women (5950 steps per day) in other report was not similar to those in our using data (www.pref.kochi.lg.jp/˜kenkou/plan 21/plan 21_2007.pdf, accessed on June 10,2009). Kuriyama[5] and Tsuji[6] have not analyzed the difference between men and women. In addition, difference of daily step counts between men and women was reported in Health Japan 21[1]. Therefore, clinical impact of daily step counts in men may not be similar to that in women.

In conclusion, daily step counts in men were associated with medical costs by ecological study. Further studies are needed in Japan to investigate the link between daily step counts and medical costs.

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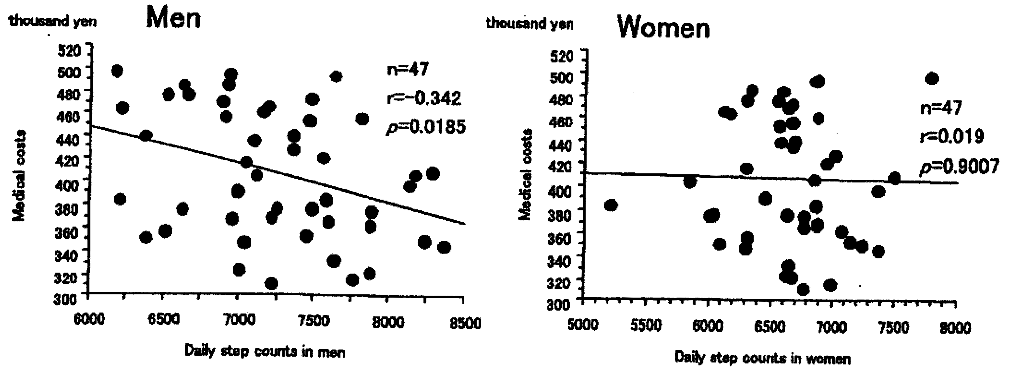

Figure: Simple correlation analysis between medical costs and daily step counts in each prefecture in Japanese.

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SHORT COMMUNICATION

Evaluation of ventilatory threshold and its relation to exercise habits among Japanese

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Abstract
Objective The aim of this study was to evaluate aerobic exercise levels, expressed in terms of ventilatory threshold (VT), in a Japanese population and explore the relationship between VT and exercise habits in this population.
Methods This was a cross-sectional study in which data collected from 547 men and 524 women aged 20–69 years and not on medications, were used to assess exercise habits and parameters at VT, namely, oxygen uptake, work rate, and heart rate.
Results Age-related changes in parameters at VT were noted. Of the participants, 205 men (37.5%) and 142 women (27.1%) had exercise habits. Oxygen uptake and work rate at VT in subjects with exercise habits were significantly higher than those without exercise habits after age had been adjusted for in both sexes. Anthropometric parameters were significantly correlated with oxygen uptake at VT, and the highest correlation coefficient rate was found between oxygen uptake at VT and body fat percentage (men $r = -0.589$, women $r = -0.631$).
Conclusion The mean values determined here may provide a useful database for evaluating VT in Japanese adult subjects.

Keywords Exercise habits · Heart rate · Oxygen uptake · Ventilatory threshold · Work rate

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Introduction

Regular physical activity has been shown to increase the level of high-density lipoprotein (HDL) in the blood and to reduce resting blood pressure, abdominal fat, triglyceride and fasting blood sugar levels, and insulin responses to the oral glucose challenge test [1–5]. The National Nutrition Survey in Japan [6] estimated that among the general Japanese population, only 29.1% of men and 25.6% of women exercised regularly (exercise habits). This report also recommended that the proportion of the population with exercise habits should be increased to 39% of men and 35% of women by 2010.

In 2006, the Japanese Ministry of Health, Labor and Welfare-sponsored study Exercise and Physical Activity Reference Quantity for Health Promotion 2006 (EPARQ 2006) recommended levels of maximal oxygen uptake as reference quantities for exercise and physical activity reference [7]. Although maximum oxygen uptake is generally considered to be an accurate and reliable parameter, it is not fully applicable to the general population in clinical practice. Ventilatory threshold (VT) is defined as the upper limit of aerobic exercise and is also thought to serve as an accurate and reliable standard for exercise prescription [8]. Since exercise intensity at VT is not harmful to

Table 1 Clinical profiles of enrolled subjects

Clinical and demographic profile	Men	Women
Number of subjects	547	524
Age (years)	41.9 ± 10.9	44.5 ± 11.8
Height (cm)	170.0 ± 5.6	156.2 ± 5.4
Body weight (kg)	79.4 ± 14.3	65.3 ± 13.1
Body mass index (kg/m^2)	27.5 ± 4.6	26.7 ± 4.9
Abdominal circumference (cm)	91.3 ± 11.5	81.5 ± 11.5
Hip circumference (cm)	98.6 ± 7.3	96.9 ± 8.5
Body fat percentage (%)	27.5 ± 6.5	36.2 ± 6.8

Values are given as the mean ± standard deviation (SD)

cardiovascular function, it can be safely applied to patients with myocardial infarction as exercise prescription [9]. However, the link between VT and exercise habits in a large sample of Japanese has not yet been investigated.

In the study reported here, we evaluated VT in Japanese subjects and compared the results between subjects who had exercise habits and those who did not.

Subjects and methods

Subjects

This was a cross-sectional study in which data on 547 men (mean age 41.9 ± 10.9 years) and 524 women (mean age 44.5 ± 11.8 years) were evaluated. The age range of the subject cohort was 20–69 years. The participants met the following criteria (Table 1): (1) they had wanted to change their lifestyle in terms of diet and exercise habits and had undergone an annual health check-up at Okayama Southern Institute of Health; (2) their VT and exercise habits had been evaluated as part of their annual health check-up; (3) they were not taking any medications. All subjects provided written informed consent for the use of their data in the study.

Ethical approval for the study was obtained from the Ethical Committee of Okayama Health Foundation.

Anthropometric measurements

The anthropometric measurements included height, body weight, abdominal circumference, hip circumference, and body fat percentage. Height and body weight was measured by AD-6225 (A&D Co, Tokyo, Japan). The body mass index (BMI) was calculated using the formula weight/(height)^2 (kg/m^2). Abdominal circumference was measured at the umbilical level, and the hip circumference was measured at the widest circumferences over the trochanter in standing subjects after normal expiration [10]. Body fat percentage was measured by an air displacement plethysmograph called the BOD POD Body Composition System (Life Measurement Instruments, Concord, CA) [11, 12]. The coefficient variation (CV, %) for same-day tests was 2.48, that for three separate-day tests was 2.27, and that for independent operators was 4.53. There was a clear correlation between the results from BOD POD and those from dual-energy X-ray absorptiometry (DEXA) ($r = 0.910$, $P < 0.01$) [11].

Exercise testing

The subjects were asked to perform a graded ergometer exercise procedure [13]. A resting electrocardiogram (ECG) was recorded and the blood pressure was measured in each subject 2 h after breakfast. Each participant then began a graded exercise program after 3 min of pedaling on an unloaded bicycle ergometer (Excalibur V2.0; Lode BV, Groningen, the Netherlands). The profile of incremental workloads was automatically defined by the methods of Jones [13], in which the workloads reach the predicted VO_{2max} in 10 min. A pedaling cycle rate of 60 rpm was maintained. Loading was terminated when the appearance of symptoms forced the subject to stop. During the test, the ECG was monitored continuously together with the recording of the heart rate (HR). Expired gas was collected, and the rates of oxygen consumption (VO_2) and carbon dioxide production (VCO_2) were measured breath-by-breath using a cardiopulmonary gas exchange system (Oxycon Alpha; Mijnhardt, the Netherlands). The VT was determined using the standard of Wasserman et al. [8], Davis et al. [14], and the V-slope method of Beaver [15] from VO_2, VCO_2, and minute ventilation (VE). Validation and reproducibility of the VT were proven in a previous study [14]. At VT, VO_2 (ml/kg/min), work rate (W), and HR (beats/min) were measured and recorded.

Exercise habits

Data on exercise habits were obtained at interviews conducted by well-trained staff using the structured method of the National Nutrition Survey in Japan. The subjects were asked if they currently exercise (over 30 min per session, two times per week for a duration of 3 months). When the answer was "yes", they were classified as subjects with exercise habits (exercised regularly). When the answer was "no", they were classified as subjects without exercise habits.

Statistical analysis

Data were expressed as the mean ± standard deviation (SD). Comparisons between two groups were performed

Table 2 Parameters at ventilatory threshold (VT) according to age group

Age	Men				Women			
	Number of subjects	Mean ± SD	Minimum	Maximum	Number of subjects	Mean ± SD	Minimum	Maximum
Oxygen uptake at VT (ml/kg/min)								
20–29	85	15.8 ± 4.7	9.3	33.9	79	13.4 ± 3.2	9.3	23.5
30–39	149	15.0 ± 4.1	8.7	31.2	96	13.7 ± 3.6[a]	9.2	27.3
40–49	167	14.9 ± 3.4	8.7	29.8	155	12.3 ± 2.0[a,b]	8.3	20.2
50–59	117	14.0 ± 2.5[a]	10.1	24.6	138	11.9 ± 1.9[a,b]	7.8	18.9
60–69	29	12.9 ± 1.7[a]	10.5	19.3	56	11.8 ± 1.8[a]	8.3	16.4
Total	547	14.8 ± 3.7	8.7	33.9	524	12.6 ± 2.6	7.8	27.3
Work rate at VT (W)								
20–29	85	92.9 ± 26.2	50.0	190.0	79	60.7 ± 16.5	30.0	125.0
30–39	149	86.4 ± 22.0	35.0	175.0	96	60.3 ± 17.4	30.0	135.0
40–49	167	80.4 ± 22.3[a]	20.0	175.0	155	50.6 ± 11.5[a,b]	20.0	90.0
50–59	117	73.2 ± 17.6[a,b]	35.0	120.0	138	47.3 ± 11.3[a,b]	15.0	102.0
60–69	29	60.1 ± 12.9[a,b,c]	35.0	85.0	56	39.9 ± 8.8[a,b,c,d]	20.0	60.0
Total	547	81.4 ± 23.0	20.0	190.0	524	51.9 ± 14.9	15.0	135.0
Heart rate at VT (beat/min)								
20–29	85	115.1 ± 11.7	85.0	149.0	79	114.1 ± 11.4	86.0	137.0
30–39	149	107.8 ± 10.1[a]	83.0	139.0	96	110.0 ± 11.7	85.0	141.0
40–49	167	105.6 ± 11.4[a]	71.0	145.0	155	107.6 ± 10.4[a]	75.0	137.0
50–59	117	99.7 ± 10.6[a,b,c]	70.0	130.0	138	103.4 ± 11.2[a,b,c]	80.0	147.0
60–69	29	98.3 ± 10.2[a,b,c]	83.0	117.0	56	98.9 ± 12.5[a,b,c]	71.0	130.0
Total	547	106.0 ± 12.0	70.0	149.0	524	107.0 ± 12.1	71.0	147.0

[a] $P < 0.05$ vs. age 20–29 years

[b] $P < 0.05$ vs. age 30–39 years

[c] $P < 0.05$ vs. age 40–49 years

[d] $P < 0.05$ vs. age 50–59 years

using the unpaired t test and covariance analysis; comparisons among more than three groups were performed by the analysis of variance (ANOVA) and Scheffe's F test. $P < 0.05$ was considered to indicate statistical significance. The Pearson's correlation coefficients were calculated to test for the significance of the linear relationship among continuous variables.

Results

Parameters at VT according to age group are summarized in Table 2. In men, oxygen uptake and work rate at VT decreased significantly with increasing age in subjects >50 years and >40 years, respectively, and HR at VT significantly decreased with increasing age in subjects >30 years. In women, oxygen uptake at VT decreased significantly with increasing age in subjects >40 years, as did both work rate and HR.

Table 3 Prevalence of subjects with exercise habits

Age	Number of subjects with (+) exercise habits (%)	Number of subjects without (−) exercise habits (%)
Men		
20–29	29 (34.1)	56 (65.9)
30–39	46 (30.9)	103 (69.1)
40–49	72 (43.1)	95 (56.9)
50–59	41 (35.0)	76 (65.0)
60–69	17 (58.6)	12 (41.4)
Total	205 (37.5)	342 (62.5)
Women		
20–29	15 (19.0)	64 (81.0)
30–39	21 (21.9)	75 (78.1)
40–49	29 (18.7)	126 (81.3)
50–59	46 (33.3)	92 (66.7)
60–69	31 (55.4)	25 (44.6)
Total	142 (27.1)	382 (72.9)

Table 4 Comparison of VT between Japanese subjects with exercise habits and those without

Parameters	Exercise habit (+)	Exercise habit (−)	P	P after adjusting for age
Men				
Age	43.2 ± 11.1	41.1 ± 10.7	0.0317*	
Oxygen uptake at VT (ml/kg/min)	16.2 ± 4.7	13.9 ± 2.5	<0.0001*	<0.0001*
Work rate at VT (W)	87.5 ± 28.0	77.7 ± 18.4	<0.0001*	<0.0001*
Heart rate at VT (beat/min)	104.9 ± 12.9	106.7 ± 11.3	0.0793	0.3660
Women				
Age	48.5 ± 12.4	43.0 ± 11.2	<0.0001*	
Oxygen uptake at VT (ml/kg/min)	13.5 ± 3.6	12.2 ± 2.1	<0.0001*	<0.0001*
Work rate at VT (W)	55.9 ± 19.4	50.4 ± 12.5	0.0002*	<0.0001*
Heart rate at VT (beat/min)	104.9 ± 12.3	107.7 ± 11.9	0.0177*	0.2195

Values are given as the mean ± SD

* Significant at $P < 0.05$

The prevalence of subjects with exercise habits is summarized in Table 3. A total of 205 men (37.5%) and 142 women (27.1%) reported exercising regularly, and the prevalence of subjects with exercise habits gradually increased with age, being highest for subjects in their 60s in both sexes (men 58.6%, women 55.4%).

We compared the VT in our subjects according to Japanese subjects with and without regular exercise habits (Table 4). The HR at VT in subjects with exercise habits was similar to that in subjects without exercise habits in men. Oxygen uptake and work rate at VT in both sexes were significantly higher for subjects with exercise habits than for those without exercise habits. However, the age of subjects with exercise habits was significantly higher than that of subjects without exercise habits. Therefore, we used age as a covariate and in a covariance analysis we compared VT between our Japanese subjects with exercise habits and those without. After adjusting for age in both sexes, we found that oxygen uptake and work rate at VT were significantly higher in subjects with exercise habits than in those without.

We also compared VT between subjects with and without exercise habits according to age group (Table 5). Oxygen uptake at VT in men <50 years and in their 60s and work rate at VT in men <50 years were significantly higher in subjects with exercise habits than in those without; in comparison, HR at VT in men in their 50s was significantly lower in subjects with exercise habits than in those without. In comparison, oxygen uptake at VT in women <50 years and work rate at VT in women <60 years were significantly higher in subjects with exercise habits than in those without.

Finally, we evaluated the relationship between oxygen uptake at VT and age and anthropometric parameters (Table 6; Fig. 1). Oxygen uptake at VT was negatively correlated with age and anthropometric parameters. The highest correlation coefficient was found between oxygen uptake at VT and body fat percentage (men $r = -0.589$, women $r = -0.631$).

Discussion

In this study, we explored VT and its relation to exercise habits in a Japanese population according to age groups. This information should serve as a useful database for evaluating VT in Japanese subjects.

The prevalence of subjects with exercise habits in Japan was reported to be 29.1% of men and 25.6% of women by the National Nutrition Survey in Japan. The definition of duration in our study, namely, 3 months, was shorter than that in the survey definition, and we did not enroll subjects who took medications. The subjects participating in our study undertook annual health check-ups and exercise tests and, consequently, they may be more careful of their own health than the subjects in the National Nutrition Survey. Therefore, our results according to the analysis of subjects without medications were higher than those in the Survey.

There are only a few reports on maximal oxygen uptake as a direct measure in healthy Japanese individuals. Ohta et al. [16] reported that maximal oxygen uptake significantly decreased with age in 832 apparently healthy subjects and could be expressed as a single regression formula: y (maximal oxygen uptake in ml/kg/min) = $46.6 - 0.36 \times$ age ($r = -0.447$) in men and $y = 35.3 - 0.23 \times$ age ($r = -0.407$) in women. We also found an age-related decrease in maximal oxygen uptake among Japanese not taking medications, as reported earlier [17]. It has also been reported that there is significant loss in oxygen uptake at VT with aging [18, 19]. Sanada et al. [18] reported a negative correlation between oxygen uptake at VT and age in 1463 Japanese. Miura reported that oxygen uptake at VT was significantly correlated with age (men $r = -0.626$, women $r = -0.578$) in 610 Japanese [19]. In this latter study, an age-related

Table 5 Comparison of VT between Japanese with and without exercise habits classified by age group

Age	Men			Women		
	Exercise habits (+)	Exercise habits (−)	*P*	Exercise habits (+)	Exercise habits (−)	*P*
Oxygen uptake at VT (ml/kg/min)						
20–29	18.0 ± 5.7	14.7 ± 3.7	0.0020*	15.4 ± 4.3	12.9 ± 2.7	0.0049*
30–39	17.9 ± 5.3	13.7 ± 2.4	<0.0001*	17.4 ± 5.4	12.7 ± 1.9	<0.0001*
40–49	16.0 ± 4.4	14.0 ± 2.0	0.0001*	13.0 ± 2.4	12.1 ± 1.9	0.0403*
50–59	14.6 ± 3.1	13.7 ± 2.1	0.0759	12.4 ± 2.1	11.7 ± 1.8	0.0548
60–69	13.5 ± 1.9	12.0 ± 1.0	0.0171*	12.2 ± 1.9	11.3 ± 1.5	0.0520
Work rate at VT (W)						
20–29	104.0 ± 33.7	87.1 ± 19.2	0.0041*	74.0 ± 24.2	57.6 ± 12.4	0.0003*
30–39	99.5 ± 25.8	80.5 ± 17.2	<0.0001*	74.2 ± 26.5	56.4 ± 11.2	<0.0001*
40–49	86.4 ± 26.1	75.9 ± 17.8	0.0024*	57.4 ± 12.4	49.0 ± 10.8	0.0003*
50–59	75.4 ± 18.5	71.9 ± 17.0	0.3074	50.5 ± 10.0	45.7 ± 11.6	0.0177*
60–69	60.9 ± 15.3	59.0 ± 9.0	0.7067	41.4 ± 8.8	38.0 ± 8.7	0.1522
Heart rate at VT (beat/min)						
20–29	113.8 ± 12.8	115.7 ± 11.1	0.4803	111.7 ± 12.5	114.7 ± 11.2	0.3743
30–39	108.3 ± 10.0	107.7 ± 10.2	0.7349	110.4 ± 14.4	109.9 ± 11.0	0.8711
40–49	105.5 ± 13.1	105.6 ± 10	0.9429	105.3 ± 10.4	108.1 ± 10.4	0.2048
50–59	96.7 ± 10.7	101.3 ± 10.3	0.0262*	103.2 ± 10.6	103.5 ± 11.5	0.8475
60–69	97.3 ± 10.0	99.8 ± 10.8	0.5338	100.2 ± 12.5	97.3 ± 12.6	0.3916

Values are given as the mean ± SD

* Significant at $P < 0.05$

Table 6 Simple correlation analysis between oxygen uptake at VT threshold and age and anthropometric parameters

Age/anthropometric parameters	Men		Women	
	r	*P*	*r*	*P*
Age (years)	−0.193	<0.0001	−0.254	<0.0001
Body weight (kg)	−0.415	<0.0001	−0.440	<0.0001
Body mass index (kg/m^2)	−0.437	<0.0001	−0.466	<0.0001
Abdominal circumference (cm)	−0.541	<0.0001	−0.521	<0.0001
Hip circumference (cm)	−0.393	<0.0001	−0.410	<0.0001
Body fat percentage (%)	−0.589	<0.0001	−0.631	<0.0001

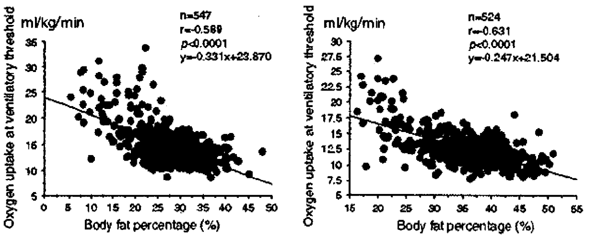

Fig. 1 Simple correlation analysis between oxygen uptake at VT and body fat percentage in Japanese

decrease of VT was noted among Japanese not taking medications. These mean values hold promise as a quite useful database for evaluating VT in Japanese subjects.

Although oxygen uptake and work rate at VT in subjects with exercise habits was significantly higher than those in subjects without exercise habits after age had been adjusted for, we found no significant differences in oxygen uptake at VT for men in their 50s and women >50 years nor in work rate at VT in men >50 years and women >60 years. According to the National Nutrition Survey in Japan, the prevalence of subjects with exercise habits increases with age, while daily step counts decrease with age [20]. Lower exercise intensity and shorter exercise time in elderly adults as well as the small sample size may make it difficult to infer causality between VT and exercise habits in these groups. Based on their analysis of 709 apparently healthy Japanese men and women, Zhang et al. [21] also showed that, relative to the subgroup with the fewest walk steps, a significantly greater peak oxygen uptake occurred only in females aged 30–49 years. However, Sandvik et al. [22] reported that physical fitness was a graded, independent, long-term predictor of mortality from cardiovascular causes in healthy, middle-aged men. Miura [19] have that oxygen uptake at VT was positively correlated with mean number of steps per day. Jones et al. [13] also reported that