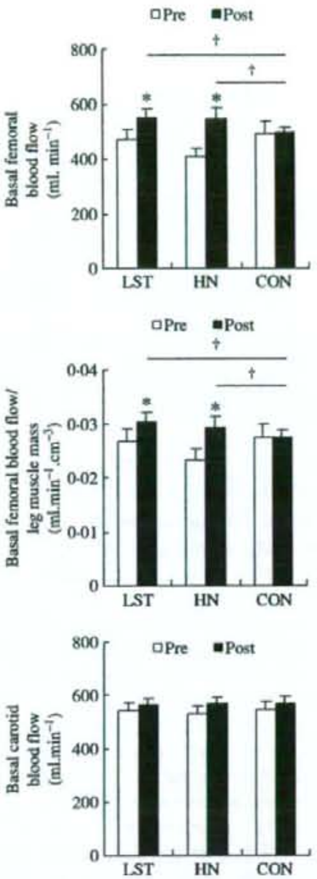

Figure 1 Basal femoral and carotid blood flow before and after the intervention period. Means ± SE ($n = 12$ for each group) in basal femoral blood flow (top), femoral blood flow/leg muscle mass (middle) and basal carotid blood flow (bottom). *Significant difference ($P<0{\cdot}05$) between pretraining and post-training values. †Significant differences ($P<0{\cdot}05$) between groups. Absolute basal femoral blood flow and that per unit volume of leg muscle mass in both training groups (LST and HN) increased significantly after experimental period.

young age may contribute to preservation of basal limb blood flow.

Potential mechanisms

What are the physiological mechanisms that would explain the increases in basal limb blood flow following resistance training? A previous study indicated that leg oxygen demand and leg muscle mass are associated with basal femoral blood flow (Dinenno et al., 2001a,b). Therefore, it was initially hypothesized that resistance training, which promotes muscular hypertrophy, increases basal femoral blood flow because muscle mass is strongly related to energy consumption (Evans & Cyr-Campbell, 1997). However, in the present study, increases in leg muscular size (3·0% in LST, 4·4% in HN) were much lower than the increases in basal femoral blood flow (18% in LST, 35% in HN), and percent changes in leg muscle mass after the experimental period were not related to those in whole-leg basal blood flow in the two training groups (LST and HN, $r = -0{\cdot}05$; Fig. 3). Moreover, increases in the relative blood flow to leg muscle mass in the two training groups were quantitatively the same as increases in whole-leg blood flow (Fig. 1). These findings suggest that qualitative changes in leg muscles by resistance training (LST and HN) have a more immediate and/or potent influence than quantitative changes (gain in muscle mass).

The muscle metabolic rate and capillary density may be qualitative factors contributing to increased basal femoral blood flow. Resistance training is known to be a strong stimulus that increases skeletal muscle turnover (syntheses and degradation) (Hasten et al., 2000) and basal metabolic demands (Ades et al., 2005), which may have acted to increase blood flow independent of muscle mass. Muscular metabolic rate was not measured, while basal metabolic rate (BMR) was measured. BMR increased after the experimental period in HN ($P<0{\cdot}01$) and in LST ($P<0{\cdot}1$) (data not shown).

An additional possible cause of the changes in leg blood flow is that peripheral blood flow may be a simple reflection of changes in systemic blood flow (cardiac output) (Leithe et al., 1984). However, there were no obvious changes in cardiac output or TPR after the intervention period, and there was no significant relation between percent changes in cardiac output and those in basal whole-leg blood flow in either training group (LST and HN, $r = 0{\cdot}19$; Fig. 4). Furthermore, basal carotid blood flow did not increase after LST and HN training. These findings suggest that the increase in basal femoral blood flow after both types of resistance training was affected not by systemic cardiovascular changes but by peripheral vascular and metabolic adaptations.

Physiological and practical implications

The present findings have potentially important physiological and practical implications. Traditional high-intensity resistance training increases muscle mass and strength. It is widely accepted that such training also facilitates performance of daily tasks, and promotes spontaneous physical activity especially in the elderly and in subjects with low physical capacity (Borst, 2004; Hunter et al., 2004). Several recent studies showed the beneficial influence of high-intensity resistance training on vascular function, contributing to increases in basal whole leg blood flow (Miyachi et al., 2005; Anton et al., 2006). The present study in healthy young men suggested that the resistance training program in the LST group promoted muscular hypertrophy without high mechanical load and increased basal femoral blood flow as efficiently as the regimen performed by the HN group. The LST regimen was not associated with either the generation of large force or marked elevation of blood

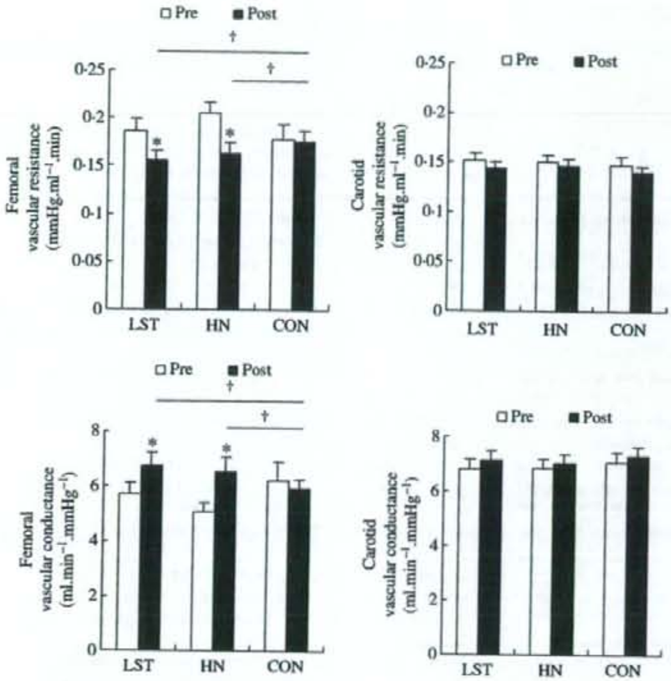

Figure 2 Femoral and carotid vascular resistance and conductance before and after the intervention period. Means ± SE (n = 12 for each group) in femoral and carotid vascular conductance (upper), femoral and carotid vascular resistance (lower) in the three experimental groups. *Significant difference (P<0·05) between pretraining and post-training values. †Significant differences (P<0·05) between groups. Femoral carotid resistance in both training groups (LST and HN) decreased, and femoral carotid conductance in both training groups (LST and HN) increased significantly after experimental period.

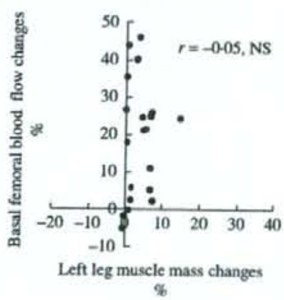

Figure 3 Relations between leg muscle mass changes and basal femoral blood flow changes in the two trained groups (n = 24). Left leg LSTM (lean soft tissue mass) is defined as left leg muscle mass. Change in leg muscle mass was not related to that in femoral leg blood flow (r = –0·05).

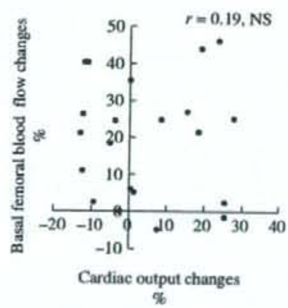

Figure 4 Relations between cardiac output changes and basal femoral blood flow changes in trained group subjects (n = 24). Change in cardio output was not related to that in basal femoral blood flow (r = 0·19).

pressure (Tanimoto & Ishii, 2006), and so it would be a safe and useful method of exercise for increasing peripheral blood flow. The reduction in leg blood flow may limit peripheral glucose uptake and contribute to glucose intolerance and hyperinsulinemia (Lind & Lithell, 1993). In addition, it may also impair the clearance of atherogenic lipids and contribute to chronic dyslipidaemia (Baron et al., 1990). Regular resistance training in the LST group may contribute to a lower incidence of cardiovascular disease through its influence on basal femoral blood flow.

Conclusion

The results of the present study indicated that resistance training, even in LST, increased basal femoral blood flow and vascular conductance as in HN, and that regular resistance training from a young age may contribute to preservation of basal limb blood flow. LST promotes muscular hypertrophy and strength gain comparable to those in HN without high mechanical load. LST is proposed as a safe and useful exercise method not only for muscular hypertrophy and strength gain, but also for increasing peripheral blood flow and vascular conductance as an additional effect. This study investigated preventive effects for healthy people, not curative effects for patients with metabolic syndrome or other diseases. Expanding this study to cover investigation in patient groups is an issue for future consideration.

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Original Article

Attenuated Increases in Blood Pressure by Dynamic Resistance Exercise in Middle-Aged Men

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Mitsuru HIGUCHI[4)], and Motohiko MIYACHI[2)]

The present study was performed to test the hypothesis that the blood pressure (BP) response to resistance exercise in middle-aged men with stiffening arteries is greater than that in young men with compliant arteries. The BP responses to acute dynamic resistance exercise (leg press) at individual relative (low, moderate and high) and absolute intensities were investigated in both young and middle-aged men. A total of 21 sedentary healthy normotensive men, 21–25 years of age (young) and 41–59 years of age (middle-aged), were included in the study. At rest, the arterial compliance (simultaneous ultrasound and applanation tonometry) and muscle strength (leg press) were lower, and indices of arterial stiffness and BP were higher in the middle-aged men than in the young men (*p*<0.05). There were no significant differences in height, body mass, or heart rate between the two groups. During exercise, the systolic BP of the middle-aged men at 80% one-repetition maximum (1RM) was significantly lower than that of the young men for the last half of the exercise period (*p*<0.05). The amounts of change in systolic and diastolic BP from baseline to the end of resistance exercise were lower in the middle-aged men than in the young men at individual relative intensities (*p*<0.05) and at individual absolute intensity. In contrast to our hypothesis, these findings indicated that the BP response during dynamic resistance exercise using large muscle groups may be attenuated in middle-aged men relative to young men. (*Hypertens Res* 2008; 31: 1045–1053)

Key Words: **aging, resistance exercise, blood pressure, pressor, arterial stiffening**

Introduction

Regular physical activity is regarded as an important component of prevention and treatment of age-related increases in cardiovascular disease (*1, 2*). Aerobic exercise in particular is recommended by major health organizations, including the American Heart Association and American College of Sports Medicine (*3, 4*), because it shows favorable effects on cardiovascular functions in young, middle-aged, and older men (*5–8*). In recent years, resistance exercise, another common exercise modality, has gained widespread acceptance in exercise prescription and cardiopulmonary rehabilitation programs and has become an integral component of comprehensive health programs endorsed by the major health organizations (*3, 9*). However, there is very little information on the potential influence of resistance training on non-musculoskeletal components, in particular the cardiovascular system. Systolic and diastolic blood pressures (BPs) rise rapidly to extremely high values during heavy weight-lifting exercise (*10*), and BPs are extreme even when exercise is performed with a relatively small muscle mass (*11, 12*). Most previous studies

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This work was supported by a Grant-in-Aid for Scientific Research (No. 13780041 to M.M.) from the Japan Society for the Promotion of Science and by a Sasagawa Scientific Research Grant (to H.K.) from the Japan Science Society.

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Received September 11, 2007; Accepted in revised form December 28, 2007.

have focused on the BP responses to resistance exercise in young adults (*13–15*), and thus have provided little information regarding BP responses in middle-aged and older individuals (*12, 16*). Furthermore, the interaction between age and BP response for dynamic resistance exercise using large muscle groups has not been reported in middle-aged men with stiffening arteries or young men with compliant arteries.

The stiffness of the large central arteries in the cardiothoracic region increases with advancing age in sedentary humans (*6, 17, 18*). This physiological alteration reduces the buffering capacity of the arteries, leading to increased pulse pressure, peripheral vessel resistance, and left ventricular wall tension (*19, 20*), all of which augment the workload of the heart. Generally, it can be assumed that middle-aged and older men with advanced arteriosclerosis would show attenuated pressor buffering function during resistance exercise. Accordingly, we hypothesized that the BP response to dynamic resistance exercise in middle-aged men with stiffening arteries would be larger than that in young men with compliant arteries. The present study was performed to clarify the differences in BP response to acute dynamic resistance exercise at individual relative or absolute intensities between young and middle-aged men.

Methods

Subjects

Twelve young (21–25 years) and nine middle-aged men (41–58 years) were recruited through various forms of advertisement or by posting on bulletin boards at our university, and had not participated in a regular exercise program for at least the previous 2 years. Only male subjects were included in the study to ensure that the interpretation of differences between the two age groups would not be confounded by the possible influence of sex. All subjects were normotensive (<140/90 mmHg), non-obese (body mass index <30 kg/m^2), and free of overt chronic diseases as assessed by medical history and physical examination. Subjects taking cardiovascular-acting medications, such as anabolic steroids, or with significant intima-media thickening, plaque formation, and/or other characteristics of atherosclerosis (*e.g.*, ankle-brachial index [ABI]<0.9) were excluded from the study. All subjects gave their written informed consent to participation in the study, and all procedures were reviewed and approved by the Institutional Review Board.

Measurements at Rest

Brachial-Ankle Pulse Wave Velocity and BP

The brachial-ankle pulse wave velocity (baPWV) and BP were assessed using a form PWV/ABI device (Colin Medical Technology, Komaki, Japan). Subjects were examined in the supine position after a rest of at least 5 min. The cuffs were wrapped on both sides of the brachium and ankle, and contained a plethysmographic sensor that determined the waveform data, including BP measurements by the oscillometric method. The baPWV was calculated as distance/time (cm/s) between the brachium and ankle. The time delay between the arrival of the pulse wave at the brachium and ankle was obtained automatically by gating the pulse wave to the peak of the R wave of the electrocardiogram. The distance was estimated from the subject's height as $L = L_a - L_b$ (L_a: path length from the heart to the ankle; L_b: path length from the heart to the brachium). Then, we used the mean of the right and left baPWV values for analysis. The measurements of baPWV and BP were performed three times per day, and the three values were averaged. The reproducibility of baPWV measurement has been validated in our laboratory (coefficient of covariance, 2±1%) and in other studies (*21, 22*).

Carotid Artery Intima-Media Thickness

The right common carotid artery intima-media thickness (IMT) was measured from images obtained using an ultrasound machine equipped with a high-resolution linear-array broad-band transducer as described previously (*23, 24*). Ultrasound images were analyzed using computerized image analysis software (NIH Image 1.63). At least 10 measurements of IMT were taken at each segment, and the mean values were used for analysis. This technique has excellent day-to-day reproducibility (coefficient of variance, 3±1%) for the carotid IMT.

Carotid Artery Compliance and Stiffness

A combination of ultrasound imaging of the pulsatile right common carotid artery with simultaneous applanation of tonometrically obtained arterial pressure from the contralateral carotid artery permits noninvasive determination of arterial compliance (*23–25*). The carotid artery diameter was measured from images obtained using an ultrasound machine equipped with a high-resolution linear-array transducer. A longitudinal image of the cephalic portion of the common carotid artery was acquired 1–2 cm distal to the carotid bulb. All image analyses were performed by the same investigator who was blinded to the group assignments.

Pressure waveforms and amplitudes were obtained from the common carotid artery with a pencil-type probe incorporating a high-fidelity strain-gauge transducer (SPT-301; Millar Instruments, Houston, USA) (*26*). As baseline levels of BP are subject to hold-down force, the pressure signal obtained by tonometry was calibrated by equating the carotid mean arterial and diastolic BP to the brachial artery value (*23–25*). In addition to arterial compliance (*27*), we also calculated the β-stiffness index, which provides an index of arterial compliance adjusted for distending pressure (*28*). Arterial compliance and the β-stiffness index were calculated using the equations $[(D_1 - D_0)/D_0]/[2(P_1 - P_0)](P_1 - P_0) \times \pi \times (D_0)^2$ and $[\ln(P_1/P_0)]/[(D_1 - D_0)/D_0]$, where D_1 and D_0 are the maximal and minimum diameters, and P_1 and P_0 are the highest and lowest BPs, respectively (*23–25*). The day-to-day coefficients of variation were 2±1%, 7±3%, and 5±2% for the carotid artery diameter, pulse pressure, and arterial compliance, respectively.

Measurements during Dynamic Resistance Exercise

Radial BP and ECG

To determine circulatory response, radial BP and ECG were recorded simultaneously in the sitting position at baseline, during exercise, and during the recovery period. ECG and radial BP waveforms were determined using arterial tonometry (JENTOW-7700; Colin Medical Technology) and standard lead electrocardiography (Life Scope 11; Nihon Kohden, Tokyo, Japan), respectively. Both ECG and arterial BP waveforms were sampled at 1,000 samples per second by connecting each device to a computer using an A/D converter (PowerLab; AD Instruments, Colorado Springs, USA). The principle of arterial tonometry is that BP at the radial artery can be obtained by measuring the reaction forces produced by flattening the radial artery. Recently, this method has become preferred over the conventional finger photoplethysmographic method (Finapres), and it has been confirmed that the accuracy and reliability of BP measured by tonometry are greater than those of BP measured by the intra-arterial method. A tonometric sensor was attached to the left wrist, and the wrist was placed on a padded platform at the level of the heart. The oscillometric calibrations were carried out for accurate tonometric measurement before, and sometimes during the main experiment (*29*).

Strength Testing

Maximal muscular strength was assessed with a leg press machine using air pressure (Keiser; Fitness Apollo Japan Co., Ltd. Tokyo, Japan). A one-repetition maximum (1RM) was determined by having the subjects perform single repetitions with progressively heavier weights, resting 2–3 min between attempts; the heaviest weight that subjects could lift once through a complete range of movement was considered their 1RM. The day-to-day coefficient of variation for 1RM strength in our laboratory is 4±2%.

Exercise Protocol I

Subjects rested under quiet conditions before beginning the leg press exercise. After a 60-s baseline period, all subjects randomly performed 10 repetitions of the leg press exercise for 40 s at each of 40%, 60%, and 80% 1RM, followed by an 80-s recovery period. One repetition was performed for 4 s (2 s for concentric and 2 s for eccentric contraction). To measure radial BP accurately, the subject's left arm was supported on an adjustable table during measurement. Subjects were stabilized in the apparatus during exercise using their right hand to hold the support handle on the seat. The left arm was allowed to rest freely by their side to avoid interference with the recording of radial BP from this arm. The subjects were encouraged to avoid deep inhalations while performing the Valsalva maneuver during the exercise. Exercise measurements were performed randomly in a day. The interval time between exercises was controlled at 10 min.

Table 1. Subject Characteristics

	Young	Middle-aged
N	12	9
Age, years	21.4±0.5	47.8±1.9
Height, cm	170.6±1.7	170.1±2.1
Body mass, kg	65.3±2.1	67.7±2.9
Resting heart rate, bpm	52.3±1.7	60.8±4.4
Brachial systolic BP, mmHg	118±3	123±4
Brachial diastolic BP, mmHg	67±2	80±3*
Brachial mean BP, mmHg	82±4	96±4*
Brachial PP, mmHg	55±4	43±2*
Carotid systolic BP, mmHg	109±2	119±6
Carotid diastolic BP, mmHg	67±2	80±3*
Carotid PP, mmHg	42±2	38±3
Carotid diastolic diameter, mm	5.9±0.1	6.7±0.3*
Carotid intima-media thickness, mm	0.48±0.02	0.63±0.02*
Carotid arterial compliance, mm^2/mmHg	0.17±0.01	0.11±0.01*
Carotid β-stiffness index, a.u.	3.95±0.28	7.30±0.76*
Brachial-ankle PWV, cm/s	1,092±38	1,291±46*
Augmentation index, %	−6.9±5.7	19.6±5.8*
Leg press maximum, kg	350±11	286±19*

Data are mean±SEM. BP, blood pressure; PP, pulse pressure; PWV, pulse wave velosity. Leg press maximum was evaluated by air pressure machine (Keiser; Fitness Apollo Japan Instruments). *Significant at $p<0.05$ *vs*. young.

Exercise Protocol II

Eleven young men and nine middle-aged men were studied using protocol II. All subjects performed 10 repetitions of the leg press exercise at individual absolute intensity (145 kgw) 10 min after the end of protocol I. Protocol II was performed using a procedure similar to that in protocol I.

Data Analysis

In the baseline period, during the leg press exercise and recovery periods, waveforms of ECG and radial BP were recorded continuously and simultaneously on a personal computer (iBook G3; Apple Computer, Cupertino, USA). Heart rate and systolic, diastolic, and mean BP were calculated using the Chart5 software package (AD Instruments). Baseline values of BP were taken as the average of the baseline period (1 min) before exercise. Average values every 4 s for one repetition and peak values of BP were obtained during the 40-s exercise period. Eight BP values in the recovery period were averaged at 0–4, 4–8, 16–20, 36–40, 56–60, 76–80, 96–

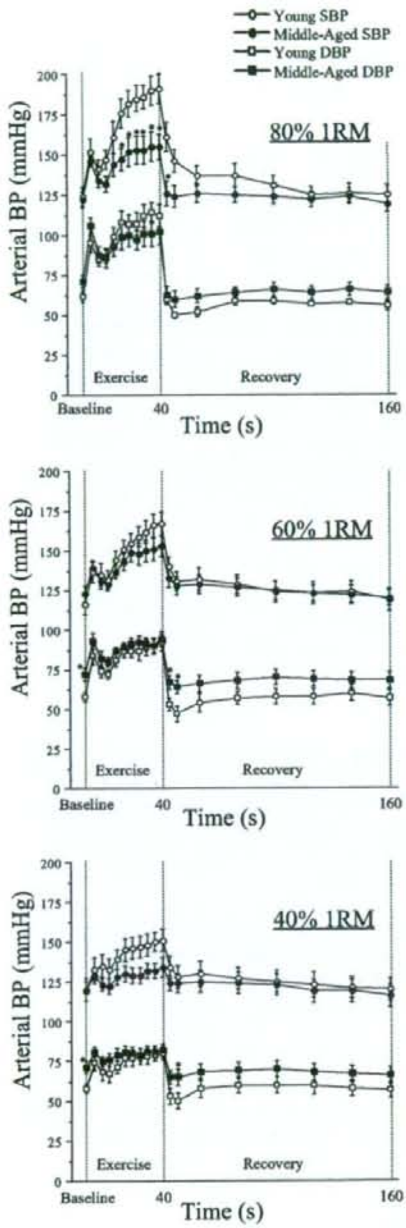

Fig. 1. *Systolic (circles) and diastolic (squares) blood pressure responses during resistance exercises and recovery periods at 40% (bottom), 60% (middle), and 80% (top) of 1RM in young (white) and middle-aged (black) men. Values are means±SEM. *p < 0.05 vs. young men.*

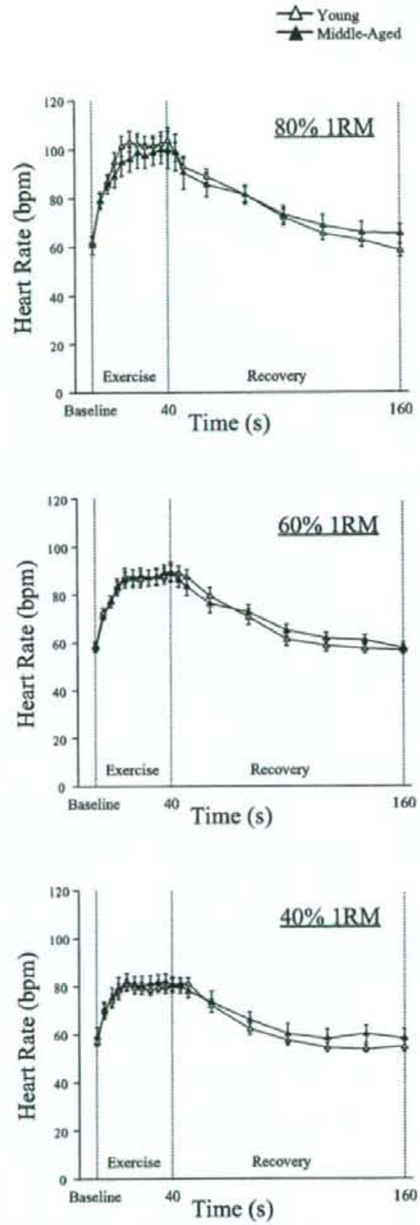

Fig. 2. *Heart rate responses during resistance exercises and recovery periods at 40% (bottom), 60% (middle), and 80% (top) of 1RM in young (white) and middle-aged (black) men. Values are means±SEM.*

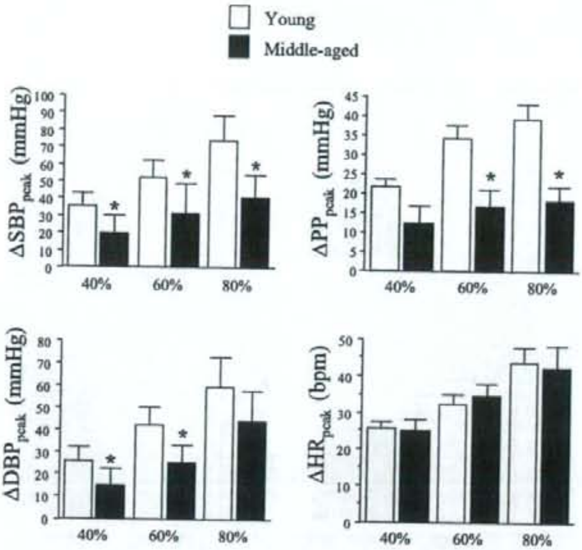

Fig. 3. *The amounts of change in systolic (SBP; top left) and diastolic (DBP; bottom left) blood pressure, pulse pressure (PP; top right) and heart rate (HR; bottom right) responses to resistance exercises at 40%, 60%, and 80% of 1RM in middle-aged (black bar) and young (white bar) men. Values are means±SEM. *$p < 0.05$ vs. young men at the same intensity.*

100, and 116–120 s. Heart rate was calculated as the peak value during exercise.

Statistical Analysis

Changes during the leg press exercise were assessed by two-way analysis of variance (group × time) with repeated measures. In the case of significant *F*-values, a post hoc test (Newman-Keuls method) was used to identify significant differences among mean values. Peak values were analyzed using the *t*-test. All data are presented as the means±SEM. Statistical significance was set at $p<0.05$ for all comparisons.

Results

Subject Characteristics

Subjects' characteristics at rest are shown in Table 1. There were no significant differences in height, weight, heart rate, or carotid BP between young and middle-aged men in the present study. Brachial diastolic and mean BP and carotid diastolic diameter were higher in the middle-aged men than in the young group ($p<0.05$). Brachial systolic BP and carotid pulse pressure were not significantly different between the two groups. β-Stiffness, augmentation index, and baPWV in the middle-aged men were significantly higher than those in the young group ($p<0.05$). The carotid arterial compliance and leg press maximum of the middle-aged men were significantly lower than those of the young men ($p<0.05$).

Exercise Protocol I

Radial systolic and diastolic BP responses during the exercise and recovery periods are shown in Fig. 1. Baseline values of radial diastolic BP under the 40% and 60% 1RM conditions were higher in middle-aged than in young men, and there were no significant differences between groups in other baseline BP values. Systolic BP for 20–40 s during exercise in the middle-aged men at only 80% 1RM was significantly lower than that in the young group ($p<0.05$). There were no significant differences in heart rate response to resistance exercise between middle-aged and young men at any intensity examined (Fig. 2). Systolic and diastolic BP returned to the baseline values within 60 s during the recovery period. The amounts of change in systolic and diastolic BP and pulse pressure from baseline to the peak response during resistance exercise were significantly lower in the middle-aged men than in the young group at all exercise intensities examined, but there was no significant difference in Δ heart rate (Fig. 3).

Exercise Protocol II

The amounts of change in systolic and diastolic BP and pulse pressure from baseline to the peak response during resistance

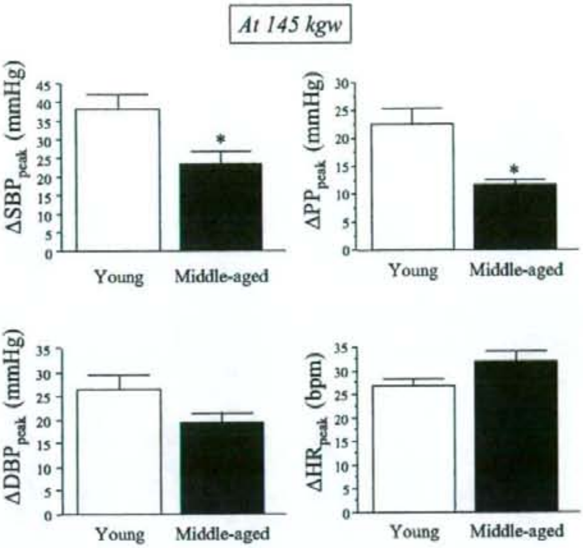

Fig. 4. *The amounts of change in systolic (SBP; top left) and diastolic (DBP; bottom left) blood pressure, pulse pressure (PP; top right) and heart rate (HR; bottom right) responses to resistance exercise at 145 kgw in middle-aged (black bar) and young (white bar) men. Values are means±SEM. *$p<0.05$ vs. young men.*

exercise were lower in the middle-aged men than in the young men at individual absolute intensity, but there was no significant difference in Δheart rate (systole, $p=0.019$; diastole, $p=0.091$; pulse pressure, $p=0.003$; Fig. 4).

Discussion

The major findings of the present study were as follows. 1) The absolute value of BP response to dynamic resistance exercise at 80% 1RM was lower in middle-aged men with stiffening arteries than in young men with compliant arteries. 2) At all relative intensities, the amounts of change in peak BP response to resistance exercise were lower in middle-aged than in young men. 3) At individual absolute intensity, the amounts of change in peak systolic BP response to resistance exercise were lower in middle-aged than in young men. In contrast to our hypothesis, these results suggest that BP responses during dynamic resistance exercise may be attenuated with advancing age at either individual relative or absolute intensity, despite age-related stiffening of the arteries.

Previous studies have suggested that the arteries of middle-aged men appear to be stiffer than those of young men based on measurements of carotid arterial compliance, β-stiffness, augmentation index, and baPWV (*5, 6, 22, 23, 30*). Our results also showed that arterial stiffening develops at a greater rate in middle-aged men than in young men. However, remarkable hypertrophy (>1.1 mm) of IMT, which is a characteristic of atherosclerosis, was not observed in any of the subjects in the present study. The maximal muscle strength estimated by the leg press exercise was lower in middle-aged men than in young men. These results indicate that the middle-aged men in the present study had developed arteriosclerosis without atherosclerosis and had lower maximal muscle strength than the young men. Although all BP values at rest in middle-aged men were higher than those in young men, all subjects were normotensive (<140/90 mmHg). Carotid diastolic diameter in middle-aged men was higher than that in young men. This result was consistent with the results of a previous epidemiological study (*31*). This alteration may be a physiological adaptation to suppress marked reductions in arterial compliance and vessel diameter induced by hypertrophied IMT with advancing age.

Dynamic resistance exercise is mainly used for health promotion and strength conditioning as it has greater effects on strength and volume of skeletal muscle in comparison with static (isometric) exercise (*32*). Understanding the pressor response during dynamic resistance exercise using large muscle groups is essential for exercise prescription. However, most previous studies have focused on static resistance exercise (*11, 12, 16, 33*), and have provided little information regarding the cardiovascular response during dynamic resistance exercise (*10*), or the interaction between age and BP response to dynamic resistance exercise using large muscle groups. We found that pressor responses during dynamic resistance exercise at relative intensities were lower in middle-aged than in young men, suggesting that the BP response to dynamic resistance exercise may be attenuated with advancing age despite age-associated arterial stiffening.

From the relative intensities, it is reasonable to hypothesize that the attenuated BP response to resistance exercise in middle-aged men may be induced by the age-related reduction in maximal muscular strength, because of the exercise intensity-associated increase in BP response to resistance exercise in both groups. In the present study, the 1RM estimated by the leg press exercise was lower in middle-aged than in young men, suggesting that the absolute intensities during exercise at individual relative intensities were lower in the former than in the latter. Accordingly, we determined BP response during the dynamic leg press exercise at individual absolute intensity (145 kgw) in the middle-aged and young men. The results indicated that the amount of change in BP response to resistance exercise was lower in middle-aged than in young men. These results suggest that age-associated reduction in muscle strength did not contribute to the attenuated pressor response to dynamic resistance exercise in middle-aged as compared with young men.

It is unclear what physiological mechanisms explain the attenuated BP responses during dynamic resistance exercise using large muscle groups in middle-aged as compared with young men. However, we speculate that the mechanism may be as follows. In middle-aged men, the muscle sympathetic nerve activity is higher at rest than in young men (*16*), whereas during exercise it is lower in the former than the latter (*16*). This results in attenuation of the increases in cardiac output and peripheral vasoconstriction induced by sympathoexcitation during exercise with advancing age (*34–36*). The ratio of high-glycolytic muscle fiber type II in skeletal muscle falls from 59% to 48% between the third and sixth decades of life (*37*), and the transformation to oxidative skeletal muscle fibers results in a lower pressor response evoked by static contraction as compared with glycolytic fibers (*38*). Therefore, alterations in sympathetic nerve activity and/or skeletal muscle fiber type with advancing age may contribute to the attenuated BP response to resistance exercise in middle-aged as compared with young men.

Sarcopenia and osteoporosis with advancing age are social problems in developed countries with aging populations. The leg press exercise used in this study, as a form of dynamic resistance exercise using predominantly the lower body, is widely accepted in exercise prescription for the prevention and rehabilitation of sarcopenia and osteoporosis, which can lead to falls and femur bone fracture, and may even result in patients becoming bedridden. However, BP rises rapidly and remarkably during high-intensity leg press exercise (*10*). Indeed, it has been reported the accidents, such as artery dissociation and subarachnoid hemorrhage, occur during resistance exercise (*39–42*). Therefore, care should be taken regarding the rapid and marked increases in BP response to resistance exercise, particularly in middle-aged and older men. In contrast to our expectations, the results of the present study indicated that pressor responses during dynamic resistance exercise at individual relative and absolute intensities were not higher in middle-aged men with stiffening arteries than in young men with compliant arteries. These results may contribute to our understanding of the cardiovascular responses to resistance exercise at appropriate intensities recommended by the major health organizations in middle-aged men who have developed arterial stiffening.

As it is the simplest parameter of arterial buffering function, pulse pressure was evaluated along with systolic and diastolic BP responses to resistance exercise in the present study. The results indicated that the amounts of change in pulse pressure response to resistance exercise at either relative or absolute intensities were lower in middle-aged men than in young men despite age-related increases in arterial stiffness. The attenuation of pulse pressure response to resistance exercise with advancing age may be affected by systolic function in the left ventricle. Of course, this function is greater in young than in middle-aged men during exercise as well as at rest. Thus, lower pulse pressure response to resistance exercise in middle-aged men may be appropriate. Pulse pressure at rest was also lower in middle-aged than in young men. As pulse pressure at rest increases progressively in normotensive subjects from the fifth decade (*43*), further studies are needed to determine BP response to resistance exercise in older men with augmented pulse pressure.

The present study had several limitations. Although there have been several reports on BP responses to isometric or aerobic exercise, we did not attempt to compare the BP responses to isometric resistance or aerobic exercise with those to dynamic resistance exercise. Compared to isometric or aerobic exercise, dynamic resistance exercise is more often used for health promotion, strength conditioning and prevention of sarcopenia or osteoporosis in middle-aged and older individuals. Therefore, as a primary approach, it was necessary to clarify the differences in BP response to dynamic resistance training using large muscle groups between young and middle-aged men. Although increases in central arterial BP during exercise may be more important than those in peripheral arterial BP from the standpoint of cardioprotection, we performed noninvasive assessment of only the radial arterial BP response to resistance exercise. Therefore, the results of the present study must be confirmed in future prospective studies focusing on central arterial BP responses to resistance exercise. Finally, the muscular strength maximum was evaluated with a leg press machine using air pressure. The value of muscular strength assessed by this machine may be different from that of muscular strength evaluated using real weights. Although the muscular strength maximum of subjects in the present study was relatively high, our results may not have been affected by this difference.

In conclusion, this study demonstrated that, at either individual relative or absolute intensity, the BP response during dynamic resistance exercise using large muscle groups was attenuated in middle-aged men as compared with young men despite age-related stiffening of the arteries. These findings may contribute to our understanding of the BP response during dynamic resistance exercise and aid in the safe performance of exercise prescription for prevention and rehabilitation of sarcopenia and osteoporosis in middle-aged and older men.

Acknowledgements

We thank Dr. Kenta Yamamoto and Dr. Izumi Tabata for their advice.

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研究

体重変化量とウエスト囲変化量との関連～8年間の変化～

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岡山県南部健康づくりセンター

Summary

Objectives : We investigated the correlation between changes in body weight and body composition parameters.

Methods : We used the data of 165 Japanese (45.2±11.1 years) at baseline and at 8year follow-up from a database of 2151 subjects, which is available at the Okayama Southern Institute of Health in Okayama prefecture, Japan. Body weight, waist circumference at the umbilical level, hip circumference, and body fat percentage were used in the analyses.

Results : Body fat percentage was significantly reduced after 8 year. Changes in body weight significantly correlated with changes in waist circumference, changes in hip circumference, and changes in body fat percentage. A decrease in body weight of 1 kg corresponded to a 0.972 cm decrease in waist circumference in men and a 1.069 cm decrease in that in women.

Conclusion : A decrease in body weight of 1 kg corresponded to an almost 1 cm decrease in waist circumference at the umbilical level in Japanese men and women.

Key words

ウエスト囲，体重，メタボリックシンドローム

はじめに

メタボリックシンドロームは，耐糖能異常や高血圧，脂質代謝異常，肥満という複数の危険因子の重複により，将来心血管疾患の発症に関与するとして注目されている。そして，心血管疾患は危険因子単独の場合より重複することで飛躍的に多くなる[1)2)]。したがって，メタボリックシンドロームを効果的に予防，改善することが重要である。

日本肥満学会（http://wwwsoc.nii.ac.jp/jasso/,accessed on July 13, 2007）では神戸宣言2006として，メタボリックシンドロームの予防，改善のために，食生活の改善と運動の増加を図り，まず3 kgの減量と3 cmのウエスト囲の減少を実現するサンサン運動を提案している。また，平成18年に厚生労働省から発表された運動指針（エクササイズガイド2006）の中でも，体重1 kgの変化はウエスト囲1 cmの変化に相当すると記載されている[3)]。しかしながら，体重変化量とウエスト囲変化量との関連についてはいまだ明らかでない。

今回私たちは，岡山県南部健康づくりセンター利用者を対象とした8年間の体重変化量とウエスト囲変化量との関連を検討した。

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対象および方法

対象は，当センターで平成9年度にヘルスチェック（健康度測定）を受けた男性717名(43.8±13.8歳)，女性1434名(43.1±13.6歳)，計2151名のうち，8年後の平成17年度にヘルスチェックを受けた男性51名（41.3±11.5歳），女性114名（46.9±10.5歳），計165名であった（表1）。

測定項目は，身長，体重，BMI（Body mass index），ウエスト囲，ヒップ囲，体脂肪率で，ウエスト囲は両足をそろえて自然に立たせ呼気時臍部で測定し，体脂肪率は空気置換法（BOD POD: Body Composition System, Life Measurement Instruments, Concord, USA）を用いて[4)5)]測定した。

結果はすべて平均値±標準偏差で表し，有意差検定は対応のある t 検定を，体重と各指標との関係はピアソンの相関係数を用い，5％未満を有意とした。

なお，本検討に関しては，岡山県健康づくり財団倫理委員会の承認を得た。

結　　果

平成17年度のヘルスチェックでは，平成9年度に比較して，男性で体脂肪率が有意に減少し，女性では，体重，BMI，体脂肪率が有意に減少したが，その他の項目では有意な変化は認められなかった（表1）。

体重の変化量とウエスト囲，ヒップ囲，体脂肪率の変化量との間には，男女ともそれぞれ有意な関連が認められた（表2）。回帰式は，男性で，ウエスト囲変化量=0.972×体重変化量−0.169，女性で，ウエスト囲変化量=1.069×体重変化量+1.151となり，体重変化量1 kgはウエスト囲変化量1 cmにほぼ相当した（表2，図）。

表1　平成9年度と平成17年度での身体組成の変化

	平成9年度	平成17年度	p
全　体			
症例数	165		
年齢	45.2 ± 11.1		
身長（cm）	159.3 ± 8.6		
体重（kg）	58.7 ± 10.5	58.0 ± 10.6	0.0850
BMI（kg / m²）	23.0 ± 3.0	22.8 ± 3.0	0.1112
ウエスト囲（cm）	75.2 ± 9.1	75.3 ± 9.1	0.9147
ヒップ囲（cm）	91.1 ± 5.0	90.8 ± 5.2	0.2076
体脂肪率（%）	29.6 ± 6.6	27.7 ± 7.4	<0.0001
男　性			
症例数	51		
年齢	41.3 ± 11.5		
身長（cm）	169.1 ± 5.1		
体重（kg）	68.6 ± 9.0	68.7 ± 8.9	0.9556
BMI（kg / m²）	24.0 ± 2.9	24.0 ± 3.0	0.9467
ウエスト囲（cm）	82.6 ± 7.8	82.5 ± 8.0	0.9019
ヒップ囲（cm）	93.2 ± 4.5	93.0 ± 4.8	0.7240
体脂肪率（%）	24.3 ± 5.4	22.4 ± 6.6	0.0212
女　性			
症例数	114		
年齢	46.9 ± 10.5		
身長（cm）	155.0 ± 5.7		
体重（kg）	54.2 ± 7.7	53.2 ± 7.4	0.0084
BMI（kg / m²）	22.6 ± 2.9	22.2 ± 2.9	0.0246
ウエスト囲（cm）	71.9 ± 7.6	72.0 ± 7.6	0.7901
ヒップ囲（cm）	90.2 ± 5.0	89.8 ± 5.1	0.1830
体脂肪率（%）	32.0 ± 5.7	30.0 ± 6.5	<0.0001

平均値±標準偏差

表2　体重変化量との相関

	r	p	回帰式
全　体			
ウエスト囲変化量（cm）	0.877	<0.0001	y=1.002x+0.699
ヒップ囲変化量（cm）	0.844	<0.0001	y=0.579x+0.051
体脂肪率変化量（%）	0.665	<0.0001	y=0.748x−1.766
男　性			
ウエスト囲変化量（cm）	0.917	<0.0001	y=0.972x−0.169
ヒップ囲変化量（cm）	0.908	<0.0001	y=0.528x−0.215
体脂肪率変化量（%）	0.692	<0.0001	y=0.746x−2.824
女　性			
ウエスト囲変化量（cm）	0.853	<0.0001	y=1.069x+1.151
ヒップ囲変化量（cm）	0.809	<0.0001	y=0.652x+0.241
体脂肪率変化量（%）	0.660	<0.0001	y=0.783x−1.258

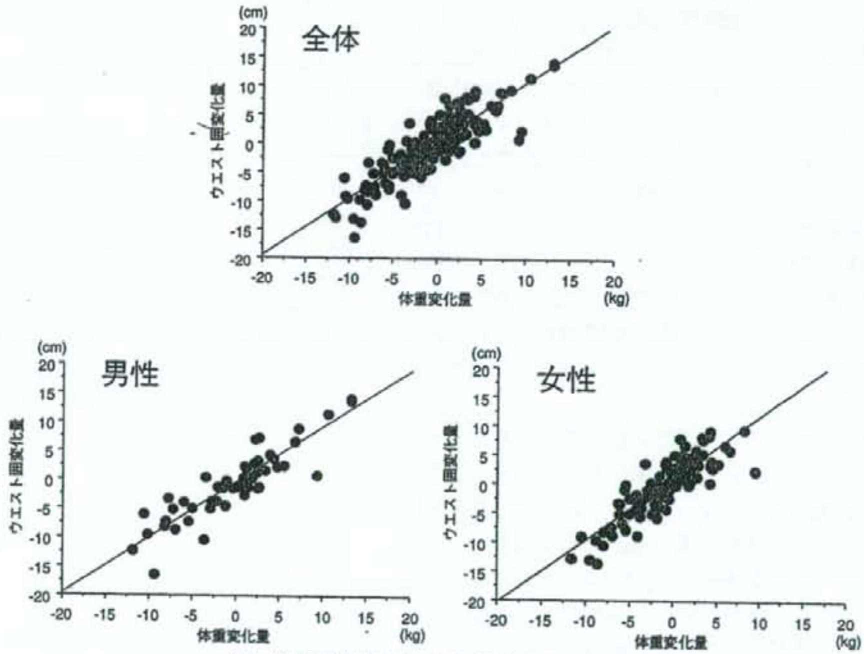

図　体重変化量とウエスト囲変化量との関連

考　察

現在わが国では，メタボリックシンドロームをはじめとした生活習慣病の適切な予防，改善法に注目が集まっている。以前，当センターにおけるメタボリックシンドロームの割合を検討したが，男性30.7%，女性3.6%であった[6]。

さらに，平成20年度からはメタボリックシンドロームの考えをとり入れた新しい健診，保健指導もスタートし，ウエスト囲の計測が必須となる。ウエスト囲は腹部肥満の簡便な指標であり，生活習慣病予防の観点からウエスト囲を減少させることは意義深い。

日本肥満学会では，肥満症，メタボリックシンドローム予防，改善のため，まずは体重3 kg，ウエスト囲3 cmの減少を提案しており，また，エクササイズガイド2006の中でも，体重1 kg（7,000kcal）はウエスト囲1 cmに相当すると記載されている。しかし，日本人における体重変化量とウエスト囲変化量に関する検討はわずかである。

以前，私たちが行なった男性肥満者に対する

1年間の運動プログラム（1回90分，週1回で食事のアドバイスは特に行なわず，運動中心の介入）を用いた検討では，体重3.3kgの減少が，ウエスト囲4.2cmの減少に相当した[7]。また，ヘルスチェック受診者のうち，1年間隔で2回受診し，生活習慣病などで薬物療法を受けていない男性856名，女性1779名で，体重変化量とウエスト囲変化量との関連についての検討では，回帰式の傾きは男性1.069，女性0.950となり体重変化量1kgはウエスト囲変化量1cmにほぼ相当した[8]。今回の結果もほぼ同様の結果であったことから，8年間にもおよぶ長期にわたっての体重変化量とウエスト囲変化量との関連についても体重変化量1kgはウエスト囲変化量1cmにほぼ相当することがわかった。

今回の検討での問題点は，まず，体重変化量とウエスト囲変化量との関連は検討できたが，メタボリックシンドロームの予防，改善のための体重減少量とウエスト囲減少量とのカットオフ値を検討することはできなかった。また，内臓脂肪面積の測定を直接行なっておらず，内臓脂肪蓄積と身体組成との関連も検討することができなかったため，今後は腹部CTを用いた内臓脂肪面積の測定を行なう必要があると思われた。

以上，当センター利用者を対象とした8年間という比較的長期の体重変化量とウエスト囲変化量との関連を検討した結果，体重変化量1kgは，ウエスト囲変化量1cmにほぼ相当した。今後は，メタボリックシンドロームの予防，改善のために有効なプログラムを計画し，さらなる介入研究が必要であると思われた。

まとめ

当センター利用者を対象とした8年間という比較的長期の体重変化量とウエスト囲変化量との関連を検討した結果，体重変化量1kgは，ウエスト囲変化量1cmにほぼ相当した。

本研究の内容の一部は第38回岡山県医学検査学会で発表予定。

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DIABETES RESEARCH AND CLINICAL PRACTICE 80 (2008) e1–e5

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Brief report

Comparison of serum uric acid levels between Japanese with and without metabolic syndrome

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ARTICLE INFO

Article history:
Accepted 1 October 2007
Published on line 7 March 2008

Keywords:
Metabolic syndrome
Uric acid
Abdominal obesity

ABSTRACT

Objective: The link between uric acid levels and metabolic syndrome was investigated.
Methods: We used data for 997 men and 1290 women. Metabolic syndrome was defined by a new criterion in Japan and uric acid was measured.
Results: Subjects who did not drink alcohol were evaluated. Uric acid was significantly higher in subjects with metabolic syndrome compared with subjects without the syndrome in both sexes. The presence of abdominal obesity and dyslipidemia in men and abdominal obesity in women revealed positive impacts on uric acid levels.
Conclusion: High serum uric acid may be often associated with metabolic syndrome in Japanese people, which accelerates the development of cardiovascular disease from metabolic syndrome.

1. Introduction

We previously reported that 30.7% of men and 3.6% of women were diagnosed as having metabolic syndrome [1]. Metabolic syndrome is closely linked to an increased risk for cardiovascular disease [2], proteinuria [3] and the elevation of hepatic enzymes [4]. Therefore, the prevention and improvement of metabolic syndrome is urgently required. Serum uric acid levels are said to be an independent predictor of cardiovascular disease [5]. However, the link between metabolic syndrome using the new criterion in Japan and uric acid remains to be investigated. In this study, we compared uric acid between Japanese people with and without metabolic syndrome.

2. Subjects and methods

2.1. Subjects

Using retrospective data from a data base of 14,345 subjects we extracted information from 997 men and 1290 women, aged 20–79 years, who met the following criteria (1) received annual health checkups from June 1997 to May 2006 at Okayama

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doi:10.1016/j.diabres.2007.10.031

Southern Institute of Health, (2) received fasting blood examination, and (3) obtained written informed consent.

2.2. *Serum uric acid measurements*

Serum uric acid levels were measured by the Uricase-Peroxidase method. The institutional normal range was 2.5–7.0 mg/dl.

2.3. *Anthropometric measurements*

Anthropometric parameters i.e. height, weight and waist circumference were measured. The waist circumference was measured at the umbilical level.

2.4. *Definition of metabolic syndrome*

Metabolic syndrome was defined according to the consensus definition of eight Medical Societies in Japan [6]. Men with a waist circumference in excess of 85 cm and women with a waist circumference in excess of 90 cm were diagnosed with metabolic syndrome if they had two or more of the following components: (1) dyslipidemia: triglycerides ≥ 150 mg/dl and/or HDL cholesterol < 40 mg/dl; (2) high blood pressure: blood pressure ≥ 130/85 mmHg; (3) impaired glucose tolerance: fasting plasma glucose ≥ 110 mg/dl.

2.5. *Alcohol consumption habits*

It is well known that alcohol consumption is closely linked to serum uric acid levels. Data on alcohol consumption habits were obtained at interviews by well-trained staff in a structured way. The subjects were asked if they currently drank alcohol on a regular basis. Subjects answering "yes" were classified as subjects with a drinking habit. Those answering "no" were further asked whether they had ever drunk alcohol on a regular basis. Those answering "no" were classified as subjects without a drinking habit and those answering "yes" were classified as subjects with a previous drinking habit.

2.6. *Statistical analysis*

Data are expressed as mean ± standard deviation (S.D.) values. A comparison of parameters between two groups was carried out using χ^2 test, unpaired *t* test and covariance analysis. A comparison of parameters among four groups was performed by ANOVA and Scheffe's F test: $p < 0.05$ was considered to be statistically significant.

3. Results

A total of 280 men (28.1%) and 46 women (3.6%) were diagnosed as having metabolic syndrome. The results of various parameters in subjects with and without the syndrome are indicated in Table 1. Age was significantly higher in subjects with metabolic syndrome in both sexes and thus, to avoid the influence of age on serum uric acid levels, we compared uric acid by using covariance analysis. In subjects with metabolic syndrome, uric acid was significantly higher compared with subjects without the syndrome.

We then analyzed the groups with and without each component of metabolic syndrome. Age was significantly higher in subjects with abdominal obesity, impaired glucose tolerance, dyslipidemia, and high blood pressure compared to subjects in both sexes without each component. By comparing uric acid adjusting for age, uric acid was significantly higher in subjects with abdominal obesity and dyslipidemia in men, and also in women with abdominal obesity.

To further evaluate the effect of abdominal obesity and dyslipidemia in men and abdominal obesity in women on uric acid, from enrolled subjects, we used data for 504 men and 624 women. We compared serum uric acid levels by classifying subjects into groups according to a number of different risk factors (Group A: waist circumference (−), dyslipidemia (−), impaired glucose tolerance and/or hypertension (−), Group B: waist circumference (+), dyslipidemia (−), impaired glucose tolerance and/or hypertension (−), Group C: waist circumference (+), dyslipidemia (+), impaired glucose tolerance and/or hypertension (−), Group D: waist circumference (+), dyslipidemia (+), impaired glucose tolerance and/or hypertension (+), (Table 2)). In men, uric acid in subjects in Group C and D was significantly higher than that in subjects in Group A. Uric acid in subjects in Group C was also significantly higher than that in subjects in Group B. Although there was no significant difference between Group A and Group B, uric acid in subjects in Group B was higher than that in subjects in Group A (Group A: 5.7 ± 1.0 mg/dl vs. Group B: 6.1 ± 1.3 mg/dl). In women, uric acid in subjects in Group B and D was significantly higher than that in subjects in Group A.

Although there were no significant differences in drinking habits between the two groups, in order to avoid any influence of alcohol consumption, we performed a separate analysis using only data from subjects with no drinking habit and compared uric acid levels between subjects with and without the syndrome (Table 1). Age was similar between the two male groups. An unpaired *t* test showed that, uric acid in subjects with metabolic syndrome was significantly higher than that in subjects without. In women, an age difference was noted, and uric acid in subjects with metabolic syndrome was also significantly higher even after adjusting for age by covariance analysis.

4. Discussion

We compared serum uric acid levels in subjects with and without metabolic syndrome using the new criterion in Japan.

Some studies have shown that higher serum uric acid levels are often accompanied by obesity, hypertension [7], dyslipidemia [8], and glucose intolerance [9], all of which play a causal role in the pathogenesis of cardiovascular disease. However, few studies have reported on the association between uric acid and metabolic syndrome using the new criterion in Japan. Kawamoto et al. investigated the relationship between serum uric acid concentrations and metabolic syndrome defined by the modified Japanese criteria using ultrasound image analysis, reporting that the prevalence of metabolic syndrome was significantly increased according to

Table 1 – Comparison of parameters between subjects with and without metabolic syndrome

Men	Metabolic syndrome (+)	Metabolic syndrome (–)	*p*	*p*
Number of subjects	280	717	Unpaired t test	Adjusting for age
Age	48.7 ± 10.4	45.4 ± 11.9	<0.0001	
Uric acid (mg/dl)	6.3 ± 1.5	6.0 ± 1.3		0.0133
Men	**Waist circumference (+)**	**Waist circumference (–)**	***p***	***p***
Number of subjects	508	489		
Age	47.2 ± 10.6	45.5 ± 12.6	<0.0001	
Uric acid (mg/dl)	6.3 ± 1.4	5.8 ± 1.2		0.001
Men	**Impaired glucose tolerance (+)**	**Impaired glucose tolerance (–)**	***p***	***p***
Number of subjects	249	748		
Age	50.8 ± 10.4	44.8 ± 11.6	<0.0001	
Uric acid (mg/dl)	5.8 ± 1.4	6.2 ± 1.3		0.086
Men	**Dyslipidemia (+)**	**Dyslipidemia (–)**	***p***	***p***
Number of subjects	485	512		
Age	47.2 ± 11.1	45.5 ± 12.0	0.0249	
Uric acid (mg/dl)	6.3 ± 1.4	5.9 ± 1.3		0.0266
Men	**High blood pressure (+)**	**High blood pressure (–)**	***p***	***p***
Number of subjects	585	412		
Age	48.3 ± 11.2	43.6 ± 11.6	<0.0001	
Uric acid (mg/dl)	6.2 ± 1.4	5.9 ± 1.3		0.6495
Men	**Metabolic syndrome (+)**	**Metabolic syndrome (–)**	***p***	***p***
Subjects without drinking habits				
Number of subjects	62	168		
Age	47.0 ± 12.1	45.4 ± 12.7	0.4008	
Uric acid (mg/dl)	6.3 ± 1.4	5.6 ± 1.3	0.0005	
Women	**Metabolic syndrome (+)**	**Metabolic syndrome (–)**	***p***	***p***
Number of subjects	46	1244		
Age	54.8 ± 10.1	46.9 ± 12.1	<0.0001	
Uric acid (mg/dl)	5.4 ± 1.1	4.4 ± 1.1		0.0412
Women	**Waist circumference (+)**	**Waist circumference (–)**	***p***	***p***
Number of subjects	89	1201		
Age	51.8 ± 10.8	46.9 ± 12.1	0.0002	
Uric acid (mg/dl)	5.1 ± 1.1	4.3 ± 1.0		0.0113
Women	**Impaired glucose tolerance (+)**	**Impaired glucose tolerance (–)**	***p***	***p***
Number of subjects	137	1153		
Age	55.6 ± 10.1	46.2 ± 11.9	<0.0001	
Uric acid (mg/dl)	4.7 ± 1.6	4.3 ± 1.0		0.166
Women	**Dyslipidemia (+)**	**Dyslipidemia (–)**	***p***	***p***
Number of subjects	402	888		
Age	51.5 ± 12.0	45.3 ± 11.6	<0.0001	
Uric acid (mg/dl)	4.6 ± 1.2	4.3 ± 1.0		0.6466
Women	**High blood pressure (+)**	**High blood pressure (–)**	***p***	***p***
Number of subjects	488	802		
Age	53.3 ± 10.6	43.5 ± 11.5	<0.0001	
Uric acid (mg/dl)	4.7 ± 1.2	4.2 ± 1.0		0.3705
Women	**Metabolic syndrome (+)**	**Metabolic syndrome (–)**	***p***	***p***
Subjects without drinking habits				
Number of subjects	33	799		
Age	55.9 ± 10.7	48.0 ± 12.1	0.0002	
Uric acid (mg/dl)	5.3 ± 1.2	4.4 ± 1.1		0.0369

The values are expressed as (mean ± S.D.).

Table 2 – Comparison of serum uric acid levels as classified into accumlation of risk factors

	Waist circumference	Dyslipidemia	Impaired glucose tolerance and/or high blood pressure	Number of subjects	Uric acid (mg/dl)	p
Men						
A	–	–	–	140	5.7 ± 1.0	
B	+	–	–	60	6.1 ± 1.3	
C	+	+	–	55	6.8 ± 1.2	ab
D	+	+	+	249	6.3 ± 1.5	a
Women						
A	–	–	–	568	4.2 ± 1.0	
B	+	–	–	11	5.4 ± 1.3	a
C	+	+	–	10	4.4 ± 0.9	
D	+	+	+	35	5.3 ± 1.1	a

a: $p < 0.01$ vs. Group A, b: $p < 0.05$ vs. Group B.

serum uric acid levels in women [10]. Ishizaka et al. also reported that the prevalence of metabolic syndrome showed a graded increase according to serum uric acid values in both sexes using the National Cholesterol Education Program (NCEP) Adult Treatment Panel III (ATPIII) [11]. In this study, serum uric acid levels were significantly higher in subjects with metabolic syndrome than that in subjects without the syndrome, even after strictly considering alcohol consumption. In addition, the contribution of abdominal obesity and dyslipidemia in men and abdominal obesity in women to the development of uric acid was noted. There was a difference in serum uric acid levels according to gender: being lower in women than in men, possibly because of estrogen or other steroid hormones [12]. The prevalence of metabolic syndrome in men was significantly higher than that in women using the criterion in Japan as we previously reported [4]. Although uric acid is related to hypertension and dyslipidemia in some reports [13,14], sex differences and the criterion of metabolic syndrome in Japan might have affected the results in this study.

Potential limitations remain in our study. First, the cross-sectional study design in our study makes it difficult to infer causality between metabolic syndrome and uric acid. Second, we could not prove the mechanism of the link between metabolic syndrome and uric acid. The kidney seems to play an important role in the development of metabolic syndrome [15]. It is possible that a normal kidney response to compensatory hyperinsulinemia associated with insulin resistance in non diabetic subjects contributes to the development of hyperuricemia. This is because hyperinsulinemia causes a significant decrease in the urinary excretion of serum uric acid and sodium [16]. In addition, it is reported that uric acid plays a role in platelet adhesiveness [17] and the formation of free radicals and oxidative stress [18].

In conclusion, uric acid was closely associated with metabolic syndrome in Japanese subjects. Further intervention studies are necessary to test the effect of prevention and treatment of metabolic syndrome on uric acid.

Acknowledgement

This research was supported in part by Research Grants from the Ministry of Health, Labor, and Welfare, Japan.

Conflict of interest

There are no conflicts of interest.

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