ORIGINAL ARTICLE

Blood pressure response to slow walking combined with KAATSU in the elderly

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The purpose of the present study was to examine the blood pressure and heart rate response to walking with and without blood flow restriction (KAATSU-walk) in the elderly. Seven active subjects (2 men, 5 women) aged between 64 to 78 years (mean age, 68.9 ± 6.3 years) performed walking test without (Control) and with KAATSU (cuff pressure 160 mmHg and 200 mmHg) on separate days. The exercise consisted of level walking at 67 m/min (4 km/hr) for 20 min. Systolic (SBP) and diastolic (DBP) blood pressure was recorded using an automatic blood pressure monitor, and mean arterial pressure (MAP) was calculated [MAP = DBP + (SBP - DBP)/3]. Heart rate (HR) and ratings of perceived exertion (RPE) were also recorded during the test. There were no significant differences ($P>0.05$) in blood pressure responses between the Control and KAATSU-160mmHg exercise, however significantly higher blood pressures were observed for the KAATSU-200mmHg exercise (112-127 mmHg for MAP) compared to the Control. However, these values are still lower than those of previous reported during moderate to heavy resistance exercise. The correlations between HR and MAP during each exercise condition were all statistically significant (range from $r=0.83$ to $r=0.94$; $p<0.05$). However, the intercept of the curve was highest in KAATSU-200mmHg exercise (i.e. MAP response to the same HR was higher), suggesting the increased total peripheral resistance with high occlusive pressure. In conclusion, our results indicate that during slow walk exercise with KAATSU, level of occlusive pressure can significantly impact upon the HR and MAP responses in the elderly, These findings are consistent with the idea that the occlusive pressure by itself can significantly modulate the cardiovascular response during low-intensity KAATSU-walk.

Key words: vascular occlusion, aging, blood pressure, older men and women, KAATSU-walk

INTRODUCTION

Low-intensity resistance training combined with blood flow restriction (KAATSU) has been shown to elicit significant increases in muscle size and strength (Shinohara et al., 1998; Takarada et al., 2002). Even more astounding and intriguing are the significant improvements that have been reported in muscle hypertrophy and increased knee joint strength in healthy young subjects following slow treadmill walk with KAATSU (Kaatsu-walk) (Abe et al., 2006). Furthermore, the increased isometric and isokinetic knee joint strength and thigh muscle size following six weeks of KAATSU-walk training were also confirmed in elderly subjects (Abe et al., 2008). Therefore, the KAATSU-walk training may be a potentially useful method for improving muscle function (muscle hypertrophy and increased strength and endurance) for a wide range of the population, including those in rehabilitation phase and frail elderly populations.

In Japan, the promotion of KAATSU training for people has increased the number of middle-aged and elderly men and women performing KAATSU-walk exercise. During treadmill walking without KAATSU, heart rate and cardiac output increase with a concomitant decrease in peripheral resistance so that there is only a small elevation in mean arterial blood pressure or no measurable change (Bogaard et al., 1997). In contrast, moderate to heavy resistance exercise involving large muscle groups, especially when a static component is included (i.e., isometric contraction), elicits marked increases in both systolic and diastolic blood pressure, as well as mean arterial blood pressure (Lewis et al., 1985; MacDougall et al., 1985). When comparing young to elderly subjects, the elderly exhibit either a similar or even a greater blood pressure response to isometric exercise (Bogaard et al., 1997; Smolander et al., 1998). Although walking with or without KAATSU has no static or isometric components, previous research has reported that low-intensity dynamic resistance exercise, when combined with KAATSU, slightly increases total peripheral resistance (Takano et al., 2005). However, it is not known how blood pressure would respond during KAATSU-walk in elderly subjects. Therefore the purpose of this study was to examine the blood pressure and heart rate responses to KAATSU-walk in the elderly.

METHODS

Subjects

Seven elderly subjects (2 men, 5 women; mean height and weight: 1.54 ± 0.06 m and 55.2 ± 11.2 kg, respectively) aged 64 to 78 years (mean age, 68.9 ± 6.3 years) volunteered to participate in the study. All subjects were active and participating in exercise (e.g., walking, flexibility, and/or low-impact aerobic dance exercise) more than once per week for the last year. Before acceptance into the study, a medical examination was performed, and questionnaires regarding medical history and physical activity were completed. Two (one man and woman) of 7 subjects were taking antihypertensive medications, and their blood pressure was controlled within the normal range. All subjects were informed of the methods, procedures and risks, and signed an informed consent document before participation. Prior to inclusion into this study, subjects had at least three months of KAATSU-walk training in order to ensure that the subjects were accustomed to the experimental conditions. 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.

Exercise and KAATSU Blood Flow Restriction Protocols

Each subject visited the laboratory on two occasions to complete three experimental conditions, with each visit separated by at least one week. On the first visit, subjects performed treadmill walking without KAATSU (Control), followed by KAATSU-walk with about 30 min rest between tests. During the second visit, subjects performed KAATSU-walk at different occlusive pressure. The exercise protocols for all conditions consisted of level walking at 67 m/min (4 km/hr) for 20 min. In order to create blood flow restriction for KAATSU condition, a specially designed elastic pressure belt (50 mm wide) was placed around the most proximal potion of both legs during the KAATSU-walk exercise. The belt contained a pneumatic bag along its inner surface that was connected to an electronic air pressure control systems that monitored the restriction pressure (Kaatsu-Master, Sato Sports Plaza, Tokyo). Before start of exercise, subjects rested in seated position, and the pressure cuffs were inflated to either 200 mmHg (KAATSU-200 mmHg) or 160-mmHg (KAATSU-160 mmHg) for the occlusive stimulus during the KAATSU-walk test.

Blood Pressure Measurement

Blood pressure was measured using an automatic blood pressure monitor (Model EBP-300, Minato Medical Science, Tokyo) every two minutes. A blood pressure cuff was placed about the left upper arm and three electrodes were attached to the chest for monitoring the electrocardiogram (ECG). Blood pressure and ECG signals were digitized, and the blood pressure signal was used to determine systolic (SBP) and diastolic (DBP) blood pressure. Mean arterial blood pressure (MAP) was calculated as one-third the pulse pressure plus the DBP according to the following formula [MAP = DBP + (SBP - DBP)/3]. The ECG was monitored continuously during the exercise session and was used to measure heart rate (HR) at 60-sec intervals. Ratings of perceived exertion (RPE) were also recorded every five minutes during the test.

Limb Circumference Measurements

Mid-thigh and 30% proximal lower leg circumferences were measured using a flexible tape measure before and immediately after each walking test.

Statistical Analysis

The results are expressed as means and standard deviations (SD) for all variables. A two-way analysis of variance (ANOVA) with repeated measures [Condition (KAATSU-160mmHg, KAATSU-200mmHg, and Control) x Time (rest and during exercise every 2 min)] was used to determine the statistical significance of the differences among the measured parameters. Post-hoc testing was performed by a one-way ANOVA. Statistical significance was set at $P < 0.05$.

RESULTS

There were no significant differences ($P > 0.05$) in blood pressure responses (SBP, DBP and MAP) between the KAATSU-160mmHg and Control, except at 16 and 20 min for MAP and at 16 min for DBP. However, significantly higher blood pressures were observed for the KAATSU-200mmHg exercise compared to the Control exercise ($P < 0.05$; Table 1). During the Control exercise, MAP was about 100 mmHg throughout the test, whereas the KAATSU-200mmHg exercise elicited pressures ranging between 112 and 127 mmHg. Athough not statistically different, HR responses during KAATSU-walk tended to be higher than those during Control exercise (4.3% and 6.1% for KAATSU-160mmHg and KAATSU-200mmHg, respectively). The correlations between HR and MAP during each exercise condition were all statistically significant ($r=0.94$; $r=0.83$; $r=0.86$, KAATSU-160mmHg, KAATSU-200mmHg, and Control conditions respectively), however, the location of each relationship was different (Figure 1). Although the slope of the curve during KAATSU-200mmHg was similar as compared to Control exercise, the intercept of the curve for KAATSU-200mmHg was the highest

Table 1. Changes in heart rate (HR), systolic (SBP) and diastolic (DBP) blood pressure, and mean arterial blood pressure (MAP) during walking without (Control) or with blood flow restriction (KAATSU-160 or KAATSU-200).

Parameters	Rest	Time	KAATSU-160	KAATSU-200	Control
MAP (mmHg)	91 (8)	4 -min	101 (12)	112 (12)	100 (10)
		8 -min	106 (9)	120 (7)**	102 (9)
		12-min	111 (9)	127 (9)**	100 (9)
		16-min	111 (7)*	124 (12)**	101 (8)
		20-min	115 (12)*	119 (12)**	102 (6)
SBP (mmHg)	126 (9)	4 -min	153 (9)	167 (19)	160 (16)
		8 -min	166 (9)	183 (12)**	162 (10)
		12-min	174 (13)	193 (11)**	161 (12)
		16-min	172 (7)	195 (13)**	166 (13)
		20-min	181 (16)	188 (17)*	165 (15)
DBP (mmHg)	68 (5)	4 -min	76 (14)	85 (12)*	70 (8)
		8-min	77 (11)	89 (11)*	71 (13)
		12-min	79 (10)	94 (11)**	70 (9)
		16-min	80 (8)*	89 (14)**	69 (7)
		20-min	82 (13)	85 (13)*	71 (5)
HR (beats/min)	64 (11)	4 -min	92 (13)	91 (11)	89 (12)
		8 -min	96 (12)	96 (12)	92 (13)
		12-min	97 (13)	99 (14)	91 (14)
		16-min	97 (14)	100 (16)	94 (14)
		20-min	98 (17)	102 (16)	94 (13)

*P<0.05, **P<0.01 vs. Control

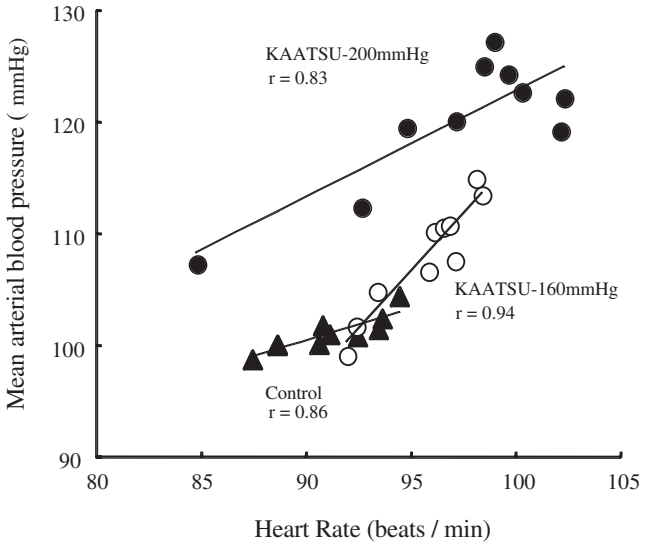

Figure 1. Relationship between heart rate and mean arterial pressure during each exercise condition. The plots are average value of 7 elderly subjects every 2 min during the test.

among three groups (i.e. MAP response to the same HR value was higher in KAATSU-200mmHg). In contrast, the slope of the regression line during KAATSU-160 was steeper compared with others, although initial value was similar as the Control. As a result, the increasing HR was associated to greater elevation of MAP than that of the Control or KAATSU-200 exercise.

The ratings of perceived exertion were similar for all exercise sessions averaging 9.3, 9.6, and 10.5 for the Control, KAATSU-160mmHg, and KAATSU-200mmHg sessions, respectively. There were no significant changes in thigh and lower leg circumferences following the Control and KAATSU-160mmHg sessions, but there were significant increases during the KAATSU-200mmHg condition (1.2±0.2 cm and 0.6±0.3 cm above baseline for the thigh and lower leg, respectively).

DISCUSSION

In the present study, MAP was slightly but not significantly elevated during the KAATSU-160mmHg exercise, however, the KAATSU-200mmHg exercise produced a significant increase in MAP of approximately 20 mmHg above Control exercise. The reasons for the increase in blood pressure during KAATSU-200mmHg exercise may be due to increases in cardiac output and/or total peripheral resistance. It is known that cardiac output is simply a product of HR and stroke volume. Therefore, HR may be a good indicator of the cardiac output response during KAATSU exercise, since there was a significant relationship between MAP and HR during each experimental condition. The fact that locations of regression lines were different between groups suggests that the KAATSU-200mmHg exercise-induced increase in blood pressure may be due not only to an increased cardiac output but it may also involve an elevated total peripheral resistance. Noradrenaline induced vasoconstrictor responses is a possible mechanism involved in the greater total peripheral resistance (Watson et al., 1979), since serum noradrenaline concentration has been shown to increase significantly during slow KAATSU-walk exercise (Abe et al. 2006) as well as during supine position at rest with KAATSU (Iida et al. 2007).

It has been well documented that moderate to high-intensity resistance exercise markedly increases both SBP and DBP, as well as MAP. MacDougall and collogues (1985) reported extreme pressure increases (SBP, 250-320 mmHg) in young bodybuilders when these individuals were exposed to 95% of one repetition maximum (1-RM) double-leg seated leg press exercises to failure. Likewise, increases in SBP (190-195 mmHg) and DBP (140-155 mmHg) were observed during one-leg knee extension with intensity between 70 and 90% of 1RM in young

males (Fleck et al., 1987). Furthermore, when older adults perform aerobic type exercise at the same relative intensity as young subjects, blood pressure responses to resistance exercise are significantly greater. For example, Bogaard and collogues (1997) reported that MAP increased continuously during an incremental exercise test for both young and middle-aged adults, and MAP response in middle-aged groups was about 20% higher than that of young group at the point of peak exercise (young, 114 ± 6 mmHg; middle-age, 137 ± 14 mmHg, $P<0.05$). For the elderly subjects in this study, MAP during KAATSU-200mmHg exercise was significantly higher than that of the Control exercise (112-127 and 100-102 mmHg respectively), however these values are lower than those of previous studies which utilized moderate to heavy resistance exercise in young men, (MacDougall et al., 1985; Fleck et al., 1987) and with older adults at maximum aerobic exercise (Bogaard et al., 1977; Miyazawa & Yamaguchi, 1984). Even though DBP was not elevated during either KAATSU walking condition unlike that observed during heavy resistance exercise, the increased SBP resulted in a large range of pulse pressure values.

There were no significant differences in RPE between the three different exercise conditions, and it is interesting to note that these elderly subjects maintained the same RPE ratings during the two KAATSU conditions as during the Control condition indicating that the potential benefits of KAATSU-walk exercise (muscle hypertrophy and increased strength) can be achieved with low levels of perceived exertion.

In summary, the blood pressure response during walk exercise with blood flow restriction may be affected by the occlusive pressure. Specifically, when elderly subjects perform slow walking with high KAATSU pressure (200 mmHg), elevations in MAP were significantly higher than control walk. These findings are consistent with the idea that the occlusive pressure by itself can significantly impact upon the cardiovascular response during low-intensity KAATSU-walk. Further investigations are required to assess the physiological significance of such changes in MAP and pulse pressure during KAATSU-walk with various occlusive stimulus.

References

Abe T, Kearns CF, Sato Y (2006) Muscle size and strength are increased following walk training with restricted venous blood flow from the leg muscle, Kaatsu-walk training. J Appl Physiol **100**: 1460- 1466.

Abe T, Sakamaki M, Fujita S, Ozaki H, Sugaya M, Sato Y, Nakajima T (2008) Effects of low-intensity walk training with restricted leg blood flow on muscle strength and aerobic capacity in elderly subjects. J Geriet Phys Ther (unpublished).

Bogaard HJ, Woltjer HH, Dekker BM, van Keimpema ARJ, Postmus PE, de Vries PMJM (1997) Haemodynamic response to exercise in healthy young and elderly subjects. Eur J Appl Physiol **75**: 435-442.

Fleck SJ, Dean LS (1987) Resistance-training experience and the pressor response during resistance exercise. J Appl Physiol **63**: 116-20.

Iida H, Kurano M, Takano H, Kubota N, Morita T, Meguro K, Sato Y, Abe T, Yamazaki Y, Uno K, Takenaka K, Hirose K, Nakajima T (2007) Hemodynamic and neurohumoral responses to the restriction of femoral blood flow by KAATSU in healthy subjects. Eur J Appl Physiol **100**: 275-85.

Lewis SF, Snell PG, Taylor WF, Hamra M, Graham RM, Pettinger WA, Blomqvist CG (1985) Role of muscle mass and mode of contraction in circulatory responses to exercise. J Appl Physiol **58**: 146-151.

MacDougall JD, Tuxen D, Sale DG, Moroz JR, Sutton JR (1985) Arterial blood pressure response to heavy resistance exercise. J Appl Physiol **58**: 785-90.

Miyazawa K, Yamaguchi I (1984) Cardiovascular response to exercise in the healthy male septuagenarians: with reference to plasma norepinephrine. Tohoku J Exp Med **134**: 177-183.

Shinohara M, Kouzaki M, Yoshihisa T, Fukunaga T (1998) Efficacy of tourniquet ischemia for strength training with low resistance. Eur J Appl Physiol **77**: 189-191.

Smolander J, Aminoff T, Korhonen I, Tervo M, Shen N, Korhonen O, Louhevaara V (1998) Heart rate and blood pressure responses to isometric exercise in young and older men. Eur J Appl Physiol **77**: 439-44.

Takano H, Morita T, Iida H, Asada K, Kato M, Uno K, Hirose K, Matsumoto A, Takenaka K, Hirata Y, Eto F, Nagai R, Sato Y, Nakajima T (2005) Hemodynamic and hormonal responses to a short-term low-intensity resistance exercise with the reduction of muscle blood flow. Eur J Appl Physiol **95**: 65-73.

Takarada Y, Sato Y, Ishii N (2002) Effects of resistance exercise combined with vascular occlusion on muscle function in athletes. Eur J Appl Physiol **86**: 308-314.

Watson RD, Hamilton CA, Reid JI, Littler WA (1979) Changes in plasma norepinephrine, blood pressure and heart rate during physical activity in hypertensive man. Hypertension **1**: 341-346.

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