Journal of Human Hypertension (2007) **21**, 96–98

www.nature.com/jhh

## RESEARCH LETTER

# Reduced central blood pressure in older adults following progressive resistance training

*Journal of Human Hypertension* (2007) **21,** 96–98.
doi:10.1038/sj.jhh.1002115; published online 9 November 2006

**The effect of a programme of resistance training on central blood pressure (BP) and arterial stiffness was studied in 17 men and women aged 65–78 years. Following 20 weeks of training, central systolic and diastolic BPs were significantly reduced by 6 and 3 mm Hg, respectively, with little change to systemic arterial stiffness. Overall, resistance training as a sole exercise intervention conferred clinically significant reductions in central BP.**

Ageing is associated with a number of changes in the cardiovascular system including an increase in large artery stiffness,[1] which gives rise to an increased brachial systolic blood pressure (SBP) and a widened pulse pressure, which may be the precursor to isolated systolic or essential hypertension.[2] Regular aerobic exercise training is known to reduce large artery stiffness[1,3] and to result in small reductions in brachial BP,[4] but less is known about the haemodynamic effects of resistance training in older adults.

A recent meta-analysis concluded that moderate intensity resistance training may be useful to prevent and combat high BP, although the authors suggested that more studies were needed on the cardiovascular effects of resistance training.[5] Owing to the pressure wave reflection, there is an increase in pulse pressure moving from the heart to the peripheral arteries, meaning that brachial artery pressures may not provide an accurate measure of the pressure load on the heart. Central (ascending aortic) blood pressures are likely to have more significance and they have been associated with clinical outcomes independently of brachial BP.[6,7] The effect of resistance training on arterial wave reflections and central BP in older adults has never been investigated and was the purpose of this pilot study.

Seventeen healthy community-dwelling older men ($n=12$) and women ($n=5$) (69.6 ± 4.7 years; body mass index (BMI) 25.8 ± 2.7 kg/m$^2$, mean ± s.d.) participating in a 20-week high-intensity resistance training programme served as subjects. Participants were free of musculoskeletal, neurological or cardiovascular disorders that would inhibit their participation in resistance exercise and none were taking vasoactive medication. Subjects underwent training twice per week and performed either a single set ($n=8$) or three sets ($n=9$) of seven upper and lower body exercises at an intensity of eight-repetition maximum.[8]

Brachial BP was measured at the dominant arm in triplicate (HEM-705CP, Omron Corporation, Kyoto, Japan). Central BP and indices of arterial stiffness were determined by pulse wave analysis (SphygmoCor, AtCor Medical, Sydney, NSW, Australia).[7] Only waveforms of high quality (i.e. pulse height and diastolic variation <5 mm Hg) were used. Measurements were made with subjects in the supine position after a 10-min rest. Systolic augmentation (Aug) was defined as the difference between the second and first systolic peaks, and the augmentation index (AIx) is Aug/pulse pressure (PP) × 100 and is a marker of systemic arterial stiffness. Estimated aortic pulse wave timing ($T_R$) was assessed by the time between the foot of the pressure wave and the inflection point. Pulse pressure amplification was calculated as the ratio of the peripheral pulse pressure to the central pulse pressure (PPP:CPP). The coefficient of variation for replicate measures of central systolic and diastolic BP is 2.7 and 5.3%, respectively, and 6.7% for AIx.

As there were no differences between the two exercise groups at the baseline and after the intervention for any haemodynamic variable, the groups were pooled to increase statistical power. Whole body muscle strength increased by 26 ± 13% ($P<0.001$) following training with no change in the body mass. Age was significantly ($P<0.05$) associated with brachial and central SBP ($r=0.563$ and 0.624), brachial and central PP ($r=0.590$ and 0.588), but not to AIx or diastolic pressures.

Peripheral and central haemodynamics are presented in Table 1. Central systolic BP and diastolic BP (DBP) at rest were significantly ($P<0.05$) reduced after training by 6 and 3 mm Hg, respectively, representing a moderate effect size. There was also a significant ($P<0.05$) decrease of 3 mm Hg in brachial DBP, whereas the 5 mm Hg reduction in brachial SBP approached significance, both changes represented a moderate effect size. In multiple regression analysis, with age, gender, type of training programme and change in brachial blood pressures entered into the model, brachial SBP and

**Table 1** Haemodynamic data at baseline and following 20 weeks of resistance training ($n = 17$)

| | *HR* (*beats/min*) | *BSBP* (*mm Hg*) | *BDBP* (*mm Hg*) | *BPP* (*mm Hg*) | *AIx* (%) | *Aug* (*mm Hg*) | $T_R$ (*ms*) | *CSBP* (*mm Hg*) | *CDBP* (*mm Hg*) | *CPP* (*mm Hg*) | *BPP:CPP* (*Ratio*) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Baseline | 64±10 | 134±11 | 77±6 | 57±11 | 30±11 | 14±6 | 143±13 | 125±10 | 78±6 | 46±9 | 1.25±0.13 |
| Week 20 | 64±9 | 129±14 | 74±9 | 55±11 | 28±10 | 12±5 | 144±15 | 119±12 | 75±9 | 44±8 | 1.26±0.10 |
| Significance (*P*-value) | 0.646 | 0.066 | 0.039 | 0.299 | 0.134 | 0.057 | 0.946 | 0.038 | 0.037 | 0.208 | 0.717 |
| Effect size | 0.05 | 0.43 | 0.43 | 0.19 | 0.18 | 0.29 | −0.02 | 0.50 | 0.44 | 0.24 | −0.07 |

Abbreviations: AIx, augmentation index; Aug, systolic augmentation; BDBP, brachial diastolic blood pressure; BPP, brachial pulse pressure; BSBP, brachial systolic blood pressure; CDBP, central diastolic blood pressure; CPP, central pulse pressure; CSBP, central systolic blood pressure; BPP:CPP, pulse pressure amplification; HR, heart rate; $T_R$, estimated aortic pulse wave timing.
Values are the mean ± s.d. Significance based on paired two-tailed *t*-test. Effect size: small difference, <0.41; moderate difference, 0.41–0.70.

DBP were independent predictors ($P<0.001$) of change in central SBP and DBP, respectively. There was a non-significant trend for a reduction in mean arterial pressure after training (pre, 97±7; post, 93±9 mm Hg; $P=0.056$). AIx was not significantly changed; however, there was a trend for a reduction in systolic augmentation. There was no significant change in resting heart rate or $T_R$.

Six participants had a resting brachial SBP>140 mm Hg. When we compared these subjects with the other participants, there was no difference for change in the brachial or central BP or AIx. Regarding medication usage, the average medication usage was 1.1±1.1 (range, 0–3), with no subjects using hypertensive medication and six participants not taking any medication. When comparing participants taking medication with those not taking medication for change in BP or AIx, there were no differences.

The primary finding of this study was that central SBP and DBP and brachial DBP were significantly reduced following resistance training. This occurred in the absence of significant change to the mean arterial pressure, resting heart rate or systemic arterial stiffness, and suggests that resistance training is beneficial to cardiovascular health in elderly individuals.

As heart rate and systemic arterial stiffness did not change, and that it would be unlikely for cardiac output to decrease following training, it is possible that exercise may have reduced peripheral vascular resistance thus lowering the intensity of the reflected pressure wave and attenuating the secondary systolic peak in the central pressure waveform. As we did not measure peripheral vascular resistance, this is only speculative. Nonetheless, exercise is known to increase nitric oxide (NO) production in peripheral arterial beds possibly owing to the increases in vascular sheer stress leading to NO-dependent vasodilation.[9] In addition, endothelial dysfunction may be improved by an exercise training programme via upregulation of endothelial NO synthase protein expression and increased bioavailability of NO.[9] As ageing also results in impaired endothelial function, exercise training may enhance endothelium-dependent vasodilation in older persons.

In contrast to the beneficial effects of resistance exercise on central BP, we observed no significant change in our measures of systemic arterial stiffness or pulse wave timing. Although aerobic exercise has been associated with an increase in central arterial compliance,[3] these relationships have not been observed for resistance training, with Miyachi *et al.*[10] reporting that 4 months of resistance training reduced arterial compliance in young adult men, and that resistance-trained middle-aged men have reduced arterial compliance.[11] Similarly, Cortez-Cooper *et al.*[12] recently reported increased arterial stiffness in young women following 11 weeks of resistance training. It may well be that resistance training is not an effective exercise mode to significantly reduce central large artery stiffness in middle-aged and older persons as ageing-induced structural alterations in the vasculature (i.e. collagen accumulation and calcium deposits) are difficult to reverse. Alternatively, 3–6 months of resistance training may not be sufficient to observe significant changes.

In conclusion, we found that central BP was significantly reduced following 20 weeks of resistance training in healthy older adults. These changes occurred independently of heart rate, arterial stiffness or body mass, and may have been related to a reduction in peripheral vascular resis-

*What is known on this topic*

- With age there is an increase in large artery stiffness and brachial systolic BP.
- Regular aerobic exercise reduces large artery stiffness and results in small reductions in brachial BP. Owing to pressure wave reflection, brachial pressures may not provide an accurate measure of the pressure load on the heart.
- The effects of resistance training on arterial wave reflections and central BP in older adults have not been investigated.

*What this study adds*

- In community-dwelling older adults not on vasoactive medication, central systolic and diastolic BP was reduced following 20 weeks resistance training.
- Resistance training in older adults has no adverse effects on systemic arterial stiffness.
- Commencing resistance exercise, even at a late age, may confer cardiovascular benefits.

Abbreviations: BP, blood pressure.

tance, although this remains to be tested. The net effect would be an attenuated cardiac after load and reduction in risk for adverse cardiovascular events.

DR Taaffe[1], DA Galvão[2], JE Sharman[1,3] and JS Coombes[1]
[1]*School of Human Movement Studies, The University of Queensland, Brisbane, Queensland, Australia;*
[2]*School of Exercise, Biomedical and Health Sciences, Edith Cowan University, Joondalup, Western Australia, Australia and*
[3]*Department of Medicine, The University of Queensland, Brisbane, Queensland, Australia*
E-mail: dtaaffe@hms.uq.edu.au
Published online 9 November 2006

## References

1 Vaitkevicius PV, Fleg JL, Engel JH, O'Connor FC, Wright JG, Lakatta LE *et al.* Effects of age and aerobic capacity on arterial stiffness in healthy adults. *Circulation* 1993; **88**: 1456–1462.
2 Sagie A, Larson MG, Levy D. The natural history of borderline isolated systolic hypertension. *N Engl J Med* 1993; **329**: 1912–1917.
3 Tanaka H, Dinenno FA, Monahan KD, Clevenger CM, DeSouza CA, Seals DR. Aging, habitual exercise, and dynamic arterial compliance. *Circulation* 2000; **102**: 1270–1275.
4 Kelley GA, Kelley KA, Tran ZV. Aerobic exercise and resting blood pressure: a meta-analytic review of randomized, controlled trials. *Prev Cardiol* 2001; **4**: 73–80.
5 Cornelissen VA, Fagard RH. Effect of resistance training on resting blood pressure: a meta-analysis of randomized controlled trials. *J Hypertens* 2005; **23**: 251–259.
6 Safar ME, Blacher J, Pannier B, Guerin AP, Marchais SJ, Guyonvarc'h PM *et al.* Central pulse pressure and mortality in end-stage renal disease. *Hypertension* 2002; **39**: 735–738.
7 The CAFE Investigators, for the Anglo-Scandinavian Cardiac Outcomes Trial (ASCOT) Investigators, CAFE Steering Committee and Writing Committee: Williams B, Lacy PS, Thom SM, Cruickshank K, Stanton A, Collier D *et al.* Differential impact of blood pressure-lowering drugs on central aortic pressure and clinical outcomes: principal results of the Conduit Artery Function Evaluation (CAFE) Study. *Circulation* 2006; **113**: 1213–1225.
8 Galvão DA, Taaffe DR. Resistance exercise dosage in older adults: single-versus multi-set effects on physical performance and body composition. *J Am Geriatr Soc* 2005; **53**: 2090–2097.
9 Green DJ, Maiorana A, O'Driscoll G, Taylor R. Effect of exercise training on endothelium-derived nitric oxide function in humans. *J Physiol* 2004; **561**: 1–25.
10 Miyachi M, Kawano H, Sugawara J, Takahashi K, Hayashi K, Yamazaki K *et al.* Unfavorable effects of resistance training on central arterial compliance: a randomized intervention study. *Circulation* 2004; **110**: 2858–2863.
11 Miyachi M, Donato AJ, Yamamoto K, Takahashi K, Gates PE, Moreau KL *et al.* Greater age-related reductions in central arterial compliance in resistance-trained men. *Hypertension* 2003; **41**: 130–135.
12 Cortez-Cooper MY, DeVan AE, Anton MA, Farrar RP, Beckwith KA, Todd JS *et al.* Effects of high intensity resistance training on arterial stiffness and wave reflection in women. *Am J Hypertens* 2005; **18**: 930–934.