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The effects of slow loaded breathing training on exercise blood pressure in isolated systolic hypertension

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Abstract

Objectives: Slow loaded breathing training has been shown to reduce resting blood pressure (BP) in isolated systolic hypertension (ISH), but it is not known whether this also reduces their exaggerated BP responses to exercise.

Methods: The study was a randomized controlled trial with block allocation stratified by sex. Twenty ISH patients (68 ± 5 yrs, 11 males) were randomized with one group undertaking 8-weeks training with slow loaded breathing (SLB: 25% maximum inspiratory pressure, 6 breaths per minute, 60 breaths every day) or deep breathing control (CON), with 8 weeks follow-up. Outcome measures were home BP and heart rate (HR) with laboratory measures of BP and HR responses to static handgrip and dynamic arm cranking exercise. Data were compared with a two-week run-in baseline.

Results: Home systolic BP fell by 22 mmHg (20–23; mean, 95% CI), diastolic BP by 9 mmHg (7–11), and HR by 12 bpm (9–15; all $p < .001$) as a result of SLB training. Systolic BP at the end of 2-min isometric handgrip was 189 ± 10 mmHg (mean, SD) before training and 157 ± 6 mmHg following SLB training. After 4-min arm exercise, systolic BP, measured at the ankle, was reduced from 243 ± 8 mmHg during the run-in period to 170 ± 15 mmHg after SLB training with no change for CON. The reduction in exercise BP, in both types of exercise, was partly due to a reduction in resting BP and to a smaller increase above resting. Systolic and pulse pressures remained below run-in values 8 weeks after the end of SLB training, and BP response to handgrip exercise remained below run-in values at 4 weeks after SLB training.

Conclusions: SLB not only reduces resting BP in ISH but also the responses to both static and dynamic exercise, potentially reducing the negative aspect of exercise for cardiovascular health.

KEYWORDS

breathing exercises, exercise, hypertension

1 | INTRODUCTION

Isolated systolic hypertension (ISH), which is characterized by systolic blood pressure (SBP) of more than 140 mmHg with diastolic blood

pressure (DBP) less than 90 mmHg (Chobanian et al., 2003), affects more than 50% of people over the age of 60 years (Cohen & Townsend, 2011; Franklin, Jacobs, Wong, L'Italien, & Lapuerta, 2001) and is a major cause of stroke, cardiovascular, and kidney disease (Lee & Oh, 2010; Weber et al., 2014). Unfortunately, for such a common and serious problem, ISH is difficult to treat, and more than 60%

The study was registered as a clinical trial (NCT 02752217).

of patients fail to meet the commonly used resting BP target of less than 140/90 mmHg (Chobanian, 2007; Mancia et al., 2013) or pulse pressure (PP) less than 50 mmHg.

In addition to resting BP, it is important to consider the responses to exercise. During dynamic exercise, at least for moderate work rates, there is an increase in systolic pressure with little or no change in diastolic pressure, but during static contractions, both systolic and diastolic pressures are raised. Although a rise in BP is a normal and necessary response to exercise, high BP at rest, and abnormally raised pressure during exercise or recovery, are all prognostic for increased risk of stroke (Kurl et al., 2001). Subjects with ISH have exaggerated BP responses to both dynamic and static exercise (Ubolsakka-Jones, Sangthong, Aueyingsak, & Jones, 2016; Ubolsakka-Jones, Sangthong, Khisanapant, & Jones, 2017) and are thus likely to be in a high-risk category.

Yoga and meditation are known to improve resting BP, and controlled slow breathing may be the common factor (Spicuzza, Gabutti, Porta, Montano, & Bernardi, 2000), and a number of experimental studies have shown benefits of slow breathing training for essential hypertension (Anderson, McNeely, & Windham, 2010; Grossman, Grossman, Schein, Zimlichman, & Gavish, 2001; Jones, Sangthong, & Pachirat, 2010; Logtenberg, Kleefstra, Houweling, Groenier, & Bilo, 2007; Mahtani, Nunan, & Heneghan, 2012; Meles et al., 2004). Although essential hypertension and ISH are assumed to have differing underlying causes, slow breathing training is also effective in reducing resting BP in ISH patients, and breathing with an inspiratory load is particularly effective (Sangthong, Ubolsakka-Jones, Pachirat, & Jones, 2016).

Given that slow loaded breathing (SLB) training can reduce the resting BP of ISH patients, the next question is whether this form of training will also reduce their exaggerated BP responses to exercise.

The beneficial effects of SLB on resting BP have been reported elsewhere (Ubolsakka-Jones, Tongdee, Pachirat, & Jones, 2018a). A subgroup of these patients also undertook exercise tests and were followed for a further 8 weeks after the end of training. The aims of the present study were to explore the effect of SLB on BP and heart rate responses to arm exercise, both static and dynamic, and to see how long any benefits persist after the end of training.

2 | METHODS

Study design

The study was a randomized controlled trial with block allocation stratified by sex, to either a SLB training group or a control (CON) group. The study had three phases: a 2-week run-in followed by an 8-week intervention of breathing training for the SLB group, which was followed by a further 8 weeks follow-up with no training (Figure 1). In addition to the home-based measurements, BP and heart rate responses to arm cranking exercise were measured in the laboratory before and after the training period, and the responses to static

hand-grip exercise was also measured before and after training and during the follow-up period. The patients continued to take their hypertension medication, which remained constant, throughout the trial and follow-up period.

Participants

Older subjects with ISH were recruited from primary care units in the local community and hospital hypertension clinic. Inclusion criteria were age 60 to 80 years with stable controlled mild to moderate ISH, defined as average resting sBP >140 mmHg and dBP < 90 mmHg at the time of diagnosis (Chobanian et al., 2003), good communication, and independent living. Exclusion criteria were secondary hypertension, use of beta-blockers, heart disease, respiratory disease, neuromuscular disease, and arm exercise limited by pain. A total of 32 patients were recruited of whom 10 were excluded for various reasons leaving 22 who took part in the trial and were randomly allocated to SLB and CON groups. Subsequently, two patients in the CON group were lost to follow-up (see Figure 1 and Table 1 for details).

The study was approved by the University Research Ethics Committee, and all subjects provided informed consent in writing.

Home-based training

The SLB group trained with a load of 25% maximum inspiratory pressure using a BreatheMAX inspiratory training device (Sangthong et al., 2016; Ubolsakka-Jones et al., 2018a). Briefly, the inspiratory resistance was set by the depth of water in the bottle, and the respiratory rate was controlled at 6 breaths per minute with 4-s inspiratory, and 6-s expiratory, time. Subjects in the CON group were instructed to use deep breathing at a normal respiratory rate. The training was undertaken at home with a total of 60 breaths a day, every day for 8 weeks. Before the start of training, the SLB participants practiced breathing with the bottle until the correct breathing pattern was established. The participants were provided with written instructions and were also shown how to measure heart rate and BP at home and record the data in a training diary.

2.2 | Measurements and data collection

Home BP and heart rate were measured with a digital oscillometric BP monitor (Riester, ri-championN, Jungingen, Germany) with an appropriately sized upper arm cuff, every morning before 9:00 am in a sitting position after resting for least 5 min. Subjects were asked to refrain from caffeine or physical activity at least 30 min before measurements were made. Heart rate and BP data were noted in a diary, together with a record of their training, during the 2-week run-in, the following 8-week training period, and the subsequent 8-week follow-up. Subjects were contacted by telephone once a week and visited at home every 2 weeks when data from the BP monitors were downloaded. Compliance with the breathing training was evaluated from the subjects' training diaries.

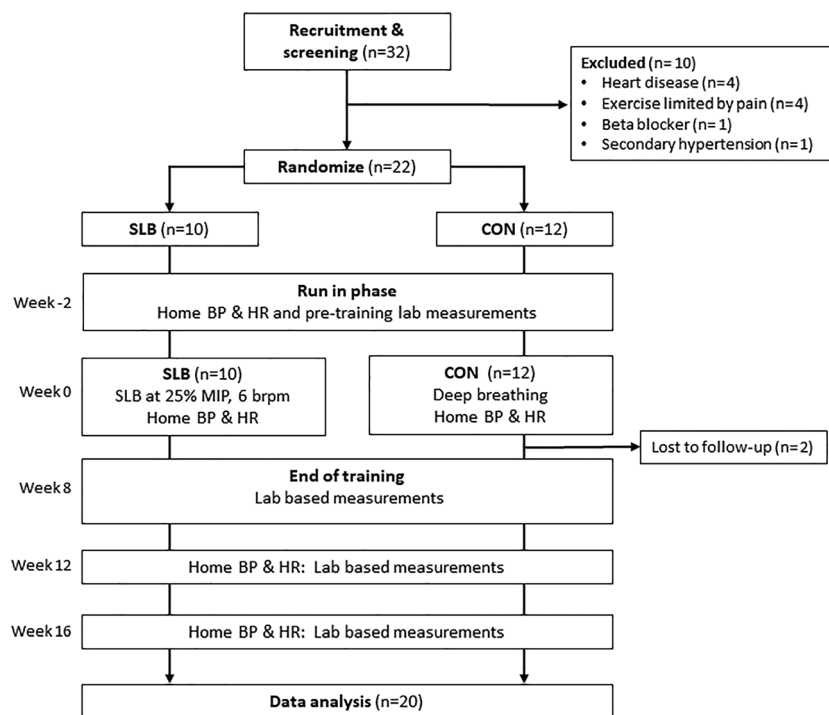


FIGURE 1 Study design and flow of subjects

TABLE 1 Subject characteristics

	SLB	CON
Subjects	10	10
M/F	5/5	6/4
Age (years)	67 ± 6	69 ± 3
Weight (kg)	68 ± 12	66 ± 11
Height (cm)	160 ± 8	159 ± 9
BMI (kg.m ⁻²)	26 ± 3	26 ± 4
sBP at diagnosis (mHg)	174 ± 6	175 ± 8
dBp at diagnosis (mmHg)	82 ± 6	84 ± 6
sBP current (mmHg)	143 ± 9	137 ± 7
dBp current (mmHg)	80 ± 8	76 ± 12
Time since diagnosis (years)	10 (1–30)	9 (3–17)
Medication		
ACE-I	7	7
CCB	5	2
alpha blocker	1	1
Diuretic	—	1
Combined	3	2
Comorbidity	7	8

Abbreviations: CON, control group; SLB, slow loaded breathing training group. Data are mean ± SD except for Time since diagnosis, which are median and range.

2.2.1 | Dynamic exercise test

Subjects undertook a constant load arm ergometer exercise test (EN 350 Endorphin Hand Cycle) to volitional fatigue, having first

undertaken a progressive exercise test to establish a load corresponding to 50% heart rate reserve (Ubloakka-Jones et al., 2018a). Tests were repeated before training and within 3 days after the end of the 8-week training period. Heart rate and BP at the ankle were measured before and every 2 min during the exercise; BP at the arm was measured before and immediately post exercise.

2.2.2 | Static exercise test

Subjects reclined in a comfortable chair with a hand dynamometer (Baseline®; Irvington, NY, USA) in their right hand, the elbow flexed, and the forearm supported on an arm rest. The maximum voluntary contraction force was measured as the best of three attempts. After 2-min rest, subjects performed an isometric hand grip contraction at 30% maximum voluntary contraction force for 2 min, based on protocols that have been used in a number of previous studies (Delaney et al., 2010; Greaney et al., 2014; Jones, Sangthong, Pachirat, & Jones, 2015). The force produced during the 2-min contraction was closely monitored, and the subjects were encouraged to maintain a constant force throughout. Heart rate and BP were measured from the left arm every minute at rest and at the end of the isometric contraction.

2.2.3 | Data analysis and statistics

Daily home data for HR and BP were averaged to provide a single weekly value for each subject. Statistical analyses were performed on home BP and HR measurement at monthly interval. Data were analysed using a repeated-measures ANOVA, followed by post hoc analysis with Bonferroni correction. All statistical analyses were performed using SPSS version 17.0 (SPSS, Ltd., Chicago, IL). Descriptive data are given as mean ± SD, and where changes are reported, these

are given as mean and 95% confidence intervals (CI). Significance was assumed for $p \leq .05$.

3 | RESULTS

There was excellent compliance with over 90% adherence to both the training programme and recording home BP and HR. Two subjects in the CON group were lost to follow-up, not attending the final laboratory session for no known reason. Data for these two patients are not included in any of the results presented here.

Resting BP and heart rate

Laboratory values for BP and heart rate before, at the end of the 8-week training period, at 12, and 16 weeks after training are given in Table 2. There were substantial decreases in all measure of BP and heart rate after 8-weeks training and at 12 and 16-week follow-up for the SLB group. There were also modest, but significantly, lower values of sBP at the end of the 8-week training period and at 12 weeks in the CON group, but otherwise, values for this group did not differ from baseline.

Home measures during the baseline run-in period were sBP, 144 ± 5.4 and 147 ± 3.9 mmHg; dBP, 76 ± 7.5 and 78 ± 5.8 mmHg; HR, 73 ± 12.4 and 72 ± 10.1 bpm (Mean $\pm$ SD, SLB and CON, respectively), values that were very similar to those measured in the laboratory at that time (compare with Table 2). The time course of changes in BP and HR, relative to the run-in baseline period are given in Figure 2, was consistent with the changes seen in the laboratory-based measurements (Table 2). Although sBP continued to decline from 4 to 8 weeks of training (Figure 2), PP reached a low and relatively steady value between 4 and 6 weeks with SLB, but with no change in CON. Following the end of training, there was a slow return of BP and HR towards baseline, and for the SLB group, sBP and PP remained significantly lower than baseline at both 12 and 16 weeks; dBP was also lower than baseline at 16 weeks, when measured in the laboratory,

but this was not significant for the home based measurements (Figure 2b).

Heart rate showed a very similar time course of change in the SLB group to that of sBP and remained lower than baseline at 12 and 16 weeks with both home and laboratory measurements (Figure 2b, Table 2).

Static hand grip exercise

Values for the increase in BP and HR above baseline after 2-min isometric handgrip exercise are given in Figure 3. The increase in sBP was significantly reduced at the end of training and at 12 weeks compared with both pretraining levels and CON (Figure 3a).

The increase in dBP at the end of handgrip exercise was significantly reduced at the end of training and at 12 weeks, compared with pretraining values but not CON (Figure 3b).

Increases of HR above baseline after 2-min handgrip exercise were significantly lower than pretraining values and CON at the end of training and at 12 and 16 weeks (Figure 3c).

Dynamic arm cranking exercise

Subjects undertook arm exercise to symptom limit, which was dyspnea in most cases. Exercise endurance approximately doubled for SLB as a result of training from 4 to 8 min, with no change in CON.

Data for sBP, measured with the arm cuff, are shown in Figure 4. After training, sBP at the end of exercise was significantly lower than pretraining (Figure 4a) but not for CON (Figure 4b). The reduction in sBP at the end of exercise for SLB was partly due to the lower resting sBP, but the increase above resting was also significantly lower after training (Figure 4c).

In contrast to the increases in sBP, dBP was reduced by 5–10 mmHg at the end of arm exercise and to similar extents both in SLB and CON before and after training.

BP measured at the ankle at the end of exercise before training was considerably higher than at the arm, being 234 ± 9 mmHg for

TABLE 2 Laboratory blood pressure and heart rate before and after training

		Pre	Post, 8 weeks	12 weeks	16 weeks
sBP (mmHg)	SLB	146 ± 3.4	$124 \pm 4.7^{a,b}$	$125 \pm 4.5^{a,b}$	$127 \pm 4.1^{a,b}$
	CON	146 ± 3.4	141 ± 3.6^a	143 ± 3.6^a	145 ± 4.1
dBP (mm Hg)	SLB	71 ± 5.4	61 ± 8.0^a	61 ± 6.8^a	62 ± 8.4^a
	CON	71 ± 6.8	66 ± 6.2	67 ± 9.2	69 ± 7.0
PP (mmHg)	SLB	75 ± 6.8	$63 \pm 5.7^{a,b}$	$64 \pm 6.4^{a,b}$	$64 \pm 7.1^{a,b}$
	CON	75 ± 7.3	76 ± 7.3	76 ± 8.3	76 ± 6.4
HR (bpm)	SLB	72 ± 13.4	59 ± 12.8^a	62 ± 13.4^a	64 ± 12.8^a
	CON	71 ± 13.8	68 ± 11.4	70 ± 12.6	72 ± 13.3

Laboratory measurements made during the run-in period before training (Pre), end of the training period (Post, 8 Weeks) and follow-up at 12 and 16 Weeks. Data are mean and SD.

Abbreviations: bpm, beats per min; CON, control group; dBP, diastolic blood pressure; HR, heart rate; PP, pulse pressure; sBP, systolic blood pressure; SLB, slow breathing group.

^aindicates within group differences compared with baseline (Pre);

^bindicates significant difference between SLB and CON.

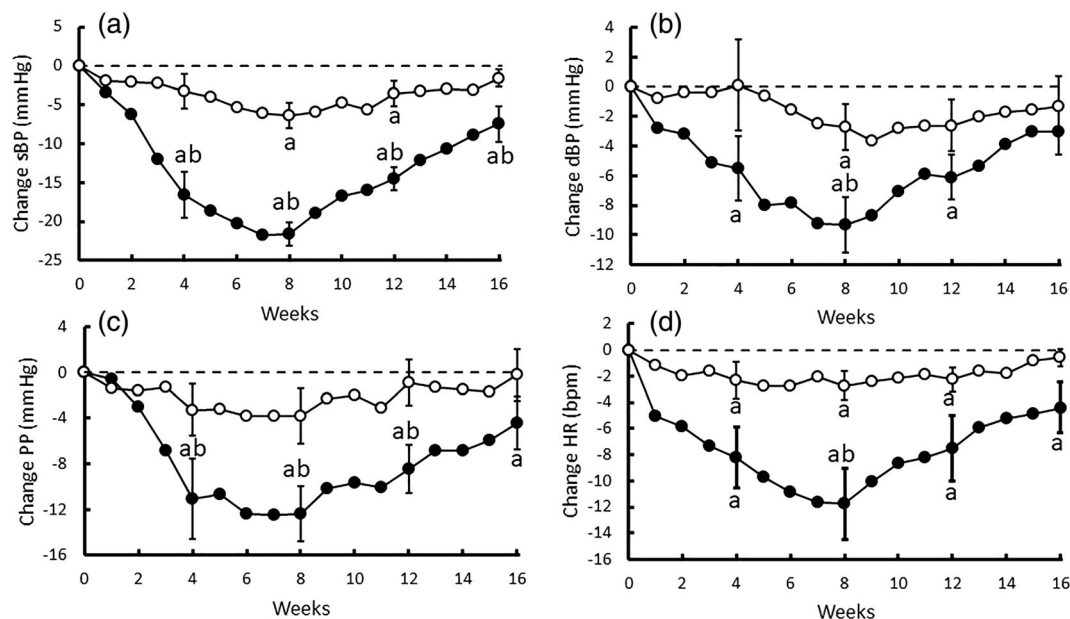


FIGURE 2 Changes in home blood pressure and heart rate compared with the pretraining run-in period, during 8-weeks training and 8-week follow-up. (a) changes in systolic blood pressure; (b) changes in diastolic pressure; (c) changes in pulse pressure; (d) changes in heart rate. Solid symbols, slow loaded breathing group; Open symbols, control. Data are mean and 95% CI. a, significant difference within group; b, significant difference between groups

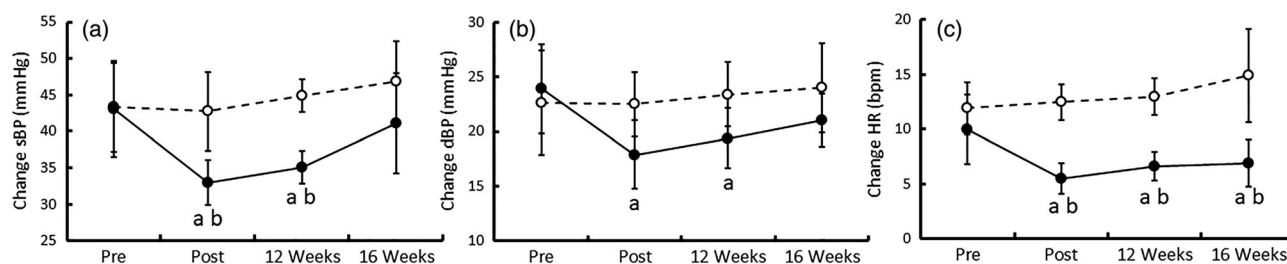


FIGURE 3 Blood pressure and heart rate responses to static handgrip exercise. Changes from rest to the end of the 2 min isometric hand grip contraction are shown for systolic blood pressure (a), diastolic blood pressure (b), and heart rate (c) before training (Pre), immediately after training (Post) and at 12 and 16-week follow up. Filled symbols and solid lines are for the slow loaded breathing group, Open symbols and dashed line for control group. Data are mean and 95% CI. a, indicates significant differences from pre-training within group; b, significant difference between groups

SLB and 235 ± 18 for CON, and this decreased to 200 ± 17 mmHg for SLB ($p < .001$) and 220 ± 13 mmHg for CON ($p = .07$) at the end of the 8-weeks training period.

There was a major difference in the time course of BP change during the exercise as a result of training (Figure 5). Before training, in both groups, and in CON after training, sBP rose rapidly in the first 2 min of exercise, whereas after SLB training, there was a slower steady increase until volitional fatigue (Figure 5a). At equal time points in the exercise, the BP responses for SLB after training were much reduced. The same results were seen for dBP (Figure 5b).

4 | DISCUSSION

Guidelines for the management of hypertension focus very much on pharmacological treatments, lifestyle, and exercise training (James et al., 2014), and although these treatments can be effective, many

patients remain poorly controlled (Chobanian, 2007; Mancia et al., 2013). Some other form of nonpharmacological treatment may be of benefit to these patients, and we have previously demonstrated that SLB is effective in reducing resting sBP (Sangthong et al., 2016; Ublosakka-Jones et al., 2018a). Although it is important to reduce resting BP, it would be valuable if the treatment also decreased the exaggerated increase in BP seen during exercise in ISH (Ublosakka-Jones et al., 2016). The results reported here show that 8 weeks of SLB training not only reduced resting BP and HR but also the responses to both static and dynamic exercise. Moreover, significant reductions in resting sBP and PP remained 8 weeks after the end of training, and the attenuated response to exercise was still evident 4 weeks after training.

Although most exercise studies commonly involve cycle or treadmill exercise, we have chosen arm cranking, partly because upper limb work is known to be particularly challenging for the cardiovascular system (Calbet et al., 2015) and partly because upper limb work is a

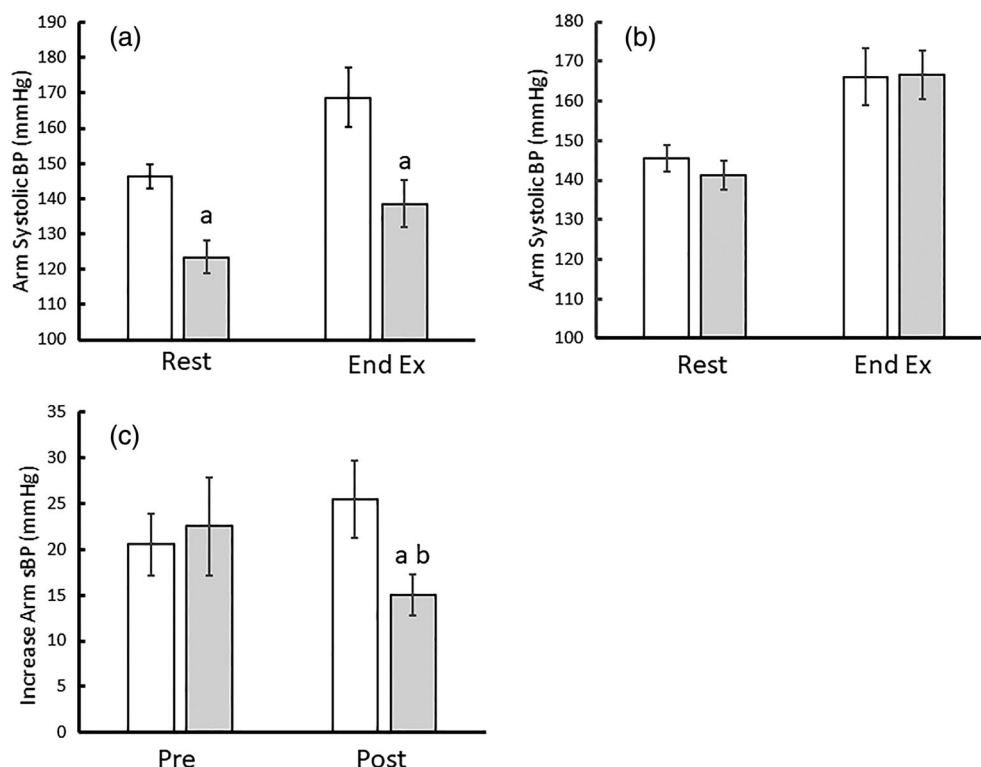


FIGURE 4 Systolic blood pressure responses to arm exercise. Subjects exercised to volitional fatigue with systolic blood pressure measured with an arm cuff at rest and immediately after the end of exercise (End Ex). (a) slow loaded breathing group; (b) control. Open bars are for exercise before the training period and filled bars are data after training. (c) the increase in systolic blood pressure above resting level at the end of exercise before training (Pre) and end of 8-weeks training (Post). Open bars control, filled bars systolic blood pressure group. Data are mean and 95% CI. a, indicates significant difference within group; b, significant difference between groups

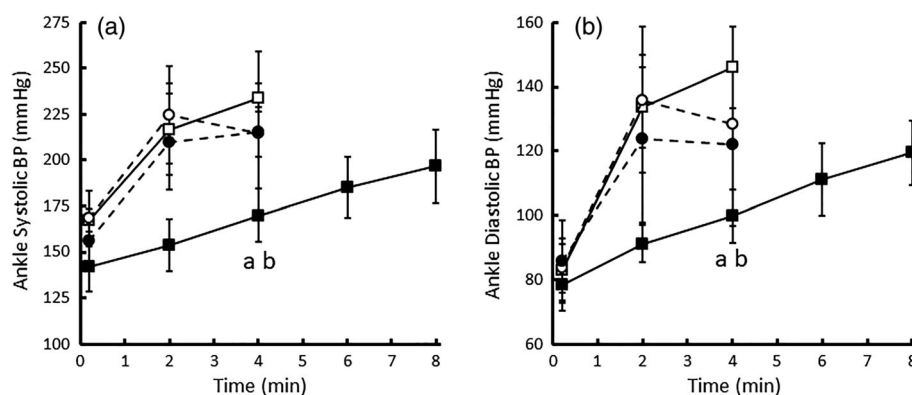


FIGURE 5 Ankle blood pressure changes during arm exercise. (a) systolic BP; (b) diastolic blood pressure. Open symbols, data before training filled symbols, at the end of the 8-week training period; circles and dashed lines control group, squares and solid lines slow loaded breathing group. Data are mean and SD. a, indicates significant difference within group; b, significant difference between groups

significant part of the daily lives of many of the patients who live and work in the rural community.

Resting BP and heart rate

Recently an sBP of less than 130 mmHg has been recommended as a treatment target for adults ≥ 65 years of age (Whelton et al., 2017; Williamson et al., 2016). The addition of SLB training to the

conventional pharmacological management in the present study was effective in bringing sBP down to levels normally seen in younger people and, with one exception, well below the new sBP target of 130 mmHg. The reductions in BP as a result of SLB training (Figure 2a) compare very favourably with the reductions of around 4 mmHg with various forms of aerobic exercise training (Whelton, Chin, Xin, & He, 2002) and 5–7 mmHg for isometric muscle training (Carlson, Dieberg, Hess, Millar, & Smart, 2014; Inder et al., 2016),

although these latter studies were generally with essential hypertension, not ISH.

PP is increasingly seen as an important risk factor for stroke, myocardial infarction, and death (Geeganage, Sare, & Bath, 2008) with the risk increasing markedly with PP over 65 mmHg (Glasser et al., 2014). In the present study, there was a substantial decrease in PP as a result of SLB training, (Table 2, Figure 2c). After training, the SLB group all had PP of 70 mmHg or less, and six out of 10 had PP < 65 mmHg.

BP and heart rate responses to static exercise

There was no normotensive CON group in the present study, but there is every reason to think that the patients had abnormally high responses to handgrip exercise before training. In a previous study of ISH (Ubolsakka-Jones et al., 2016), the upper bound (+2SD) of sBP at the end of the 2-min handgrip exercise was 156 mmHg for the normotensive age-matched subjects and 206 mmHg for the ISH patients; in the present study, the 95th percentile for the ISH patients was 209 mmHg.

The data in Figure 3 clearly show that SLB training reduced the increase above resting in response to isometric hand grip exercise. For sBP, the increase at the end of exercise was reduced by 10 mmHg whereas for dBP, the reduction was 6 mmHg (Figure 3a,b) with no change in the CON group.

BP and heart rate responses to dynamic arm ergometer exercise

Arm cranking presents some problems when measuring BP as it is clearly not possible to measure from the arms or fingers during the exercise. Diastolic BP, measured with an arm cuff decreased after arm cranking, as reported by Hong et al. (2011), presumably as a result of local vasodilation. It is likely, therefore, that sBP would also be underestimated (Hollingsworth, Bendick, Franklin, Gordon, & Timmis, 1990). Nevertheless, it was found that the increase in sBP immediately post exercise was attenuated by 5–10 mmHg as the result of SLB training (Figure 4).

The BP response to the exercise was also monitored with an ankle cuff during exercise. At the end of exercise, sBP measured at the ankle was 18 mmHg lower in the SLB group after training, with no difference in dBP (Figure 5). However, the exercise duration was twice as long after SLB training compared with pretraining and CON, and the notable feature of the data in Figure 5 is the slower rise in BP in the SLB group so that after 4-min exercise, the time when all subjects were still exercising in the pretraining phase, the difference for sBP between pre and posttraining for SLB was 45 mmHg, more than can be explained by the decrease in resting sBP. Similarly, there was a decrease of 22 mmHg for dBP at that time. These are substantial reductions in BP responses.

What is particularly notable with the present study is that the ISH patients were stable and well maintained with conventional drug therapies with sBP around 20 mmHg lower than when first diagnosed, yet the slow breathing training was able to further reduce the BP and HR

to levels comparable with healthy young adults. This implies a substantial modification of processes regulating BP.

Physiological changes in hypertension and SLB

Patients with essential hypertension show exaggerated responses to muscle contraction, and BP remains high after the end of exercise if the blood supply is occluded, indicating an increased sensitivity of the metaboreflex (Delaney et al., 2010; Greaney et al., 2014; Sausen, Delaney, Stillabower, & Farquhar, 2009), and this can be reversed by SLB training (Jones et al., 2015). But how SLB affects these processes is not clear. Probably the key feature of SLB is the long inspiratory phase (4 s) and high lung volume, which may activate pulmonary stretch reflex inhibiting sympathetic outflow (Seals et al., 1993). Slow breathing also enhances the interaction between respiratory neurones and the cardiac and autonomic centres in the brain stem. Respiratory sinus arrhythmia is much more prominent during slow breathing at around 6 breaths per minute, as used in training here, and is also greater with large lung volumes (Brown, Beightol, Koh, & Eckberg, 1993). Moreover, baroreceptor sensitivity (Eckberg, 1980; Eckberg, 2003) and muscle sympathetic nerve activity (Shantsila et al., 2015; St Croix, Satoh, Morgan, Skatrud, & Dempsey, 1999) both fluctuate during the respiratory cycle demonstrating very close links between the respiratory centres, over which there is voluntary control, and the autonomic nervous system. It is possible, therefore, that the voluntary act of slow breathing, if repeated during training, may modify the central pathways regulating resting BP and the response to exercise, as demonstrated here.

The main pathology in age-related ISH is an increased stiffness of the conduit arteries leading to faster pressure wave reflection, which augments the systolic pressure, whereas the diastolic pressure is unaffected or even decreases (Greenwald, 2007). The fact that the breathing training reduced systolic and PPs implies that the training had increased the compliance of the large arteries, although this remains to be confirmed with measurements of arterial stiffness. A meta-analysis of exercise studies (Ashor, Lara, Siervo, Celis-Morales, & Mathers, 2014) concluded that endurance, but not strength, training results in improvements in arterial stiffness. Whatever the mechanism of this training effect, it is possible that SLB might similarly increase arterial compliance. There are also indications that there are changes in the central control of BP in ISH. Older people with ISH also show an exaggerated response to muscle contraction compared with age matched normotensive subjects (Ubolsakka-Jones et al., 2016) with evidence of an increased metaboreflex, which is reduced with SLB training (Ubolsakka-Jones et al., 2017 and Figure 3 here), most likely through the same mechanism as with essential hypertension.

Limitations

A number of potential subjects were excluded from the study, mostly because of possible problems with the exercise tests; one subject on beta-blockers was withdrawn because of doubts about the heart rate

response during exercise. The selection criteria do not, however, imply that the SLB technique is of limited application. One of the limitations of the handgrip exercise is that BP was registered with an arm cuff rather than using beat-by-beat methodology. Although beat-by-beat measurements would be desirable, we have argued elsewhere (Ubolsakka-Jones et al., 2016; Ubolsakka-Jones et al., 2017) that this mainly affects the variance, but not necessarily the mean value of the measurements made at the end of the contraction because it is difficult to be very precise as to when the measurement is taken. The arm cranking exercise presents problems in terms of measuring BP, but without an indwelling arterial line, it is difficult to see how measurements at the ankle could be improved on. It would be useful to repeat these measurements with cycling or treadmill walking. There are a number of additional measurements that could be made in future studies such as baroreflex sensitivity, pulse wave velocity, stroke volume, and cardiac output as well as sympathetic nerve activity and changes in renin and in sodium and water handling in response to SLB.

4.2 | Implications for physiotherapy practice

When used in combination with conventional drug treatment, SLB training reduced systolic BP from around 140 to 120 mmHg, and there is increasing evidence that, at least for older people, a target of 120 results in significant clinical benefits (Williamson et al., 2016). If SLB were to be widely used in conjunction with conventional drug therapy, it could result in considerable savings in the cost of health care for an aging population. However, the savings and benefits of SLB would be even greater if SLB could reduce or replace the drug treatments. Further studies might, therefore, determine whether SLB can replace conventional pharmaceutical treatment and whether it is necessary for patients to train every day. The fact that the training effect persists for several weeks (Sangthong et al., 2016 and present results) suggests that once BP is reduced, it may be sufficient to train intermittently.

Encouraging exercise and physical activity is key to reducing the risks of cardiovascular disease, and it is a common component of all nearly all rehabilitation programmes. For hypertensive people, however, exercise also presents some difficulty because high sBP and PP at rest, during exercise and in recovery, are all prognostic for stroke (Kurl et al., 2001). Raised BPs during exercise can exacerbate problems with cardiac function because left ventricular hypertrophy is a common complication of ISH (Heesen et al., 1997; Pini et al., 2002). It is particularly important that the BP responses to upper body exercise are reduced because these tend to be larger and thus, potentially, more damaging, than lower body activity (Calbet et al., 2015). The present observations suggest that when prescribing exercise, it is important to be aware of the possibility of high BP responses, especially in older subjects who are very likely to suffer from ISH and that a programme of slow breathing training may help not only to reduce resting BP but also to minimize the risks associated with the high BP responses to exercise. Moreover, SLB also simultaneously improves lung capacity (Ubolsakka-Jones et al., 2018), which is important for physical rehabilitation in older people.

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CONFLICT OF INTEREST

Dr Ubolsakka-Jones is academic advisor to the company distributing BreatheMAX.

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