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Slow loaded breathing training improves blood pressure, lung capacity and arm exercise endurance for older people with treated and stable isolated systolic hypertension☆

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ABSTRACT

Background: Hypertension and reduced lung function are important features of aging. Slow loaded breathing training reduces resting blood pressure and the question is whether this can also improve lung function.
Methods: Thirty-two people (67 ± 5 years, 16 male) with controlled isolated systolic hypertension undertook an eight weeks randomised controlled training trial with an inspiratory load of 25% maximum inspiratory pressure (MIP) at 6 breaths per minute (slow loaded breathing; SLB) or deep breathing control (CON). Outcome measures were resting blood pressure (BP) and heart rate; MIP; lung capacity; chest and abdominal expansion; arm cranking exercise endurance at 50% heart rate reserve.
Results: Home based measurement of resting systolic BP decreased by 20 mm Hg (15 to 25) (Mean and 95%CI) for SLB and by 5 mm Hg (1 to 7) for CON. Heart rate and diastolic BP also decreased significantly for SLB but not CON. MIP increased by 15.8 cm H_2O (11.8 to 19.8) and slow vital capacity by 0.21 L (0.15 to 0.27) for SLB but not for CON. Chest and abdominal expansion increased by 2.3 cm (2.05 to 2.55) and 2.5 cm (2.15 to 2.85), respectively for SLB and by 0.5 cm (0.26 to 0.74) and 1.7 cm (1.32 to 2.08) for CON. Arm exercise time increased by 4.9 min (3.65 to 5.15) for SLB with no significant change for CON.
Conclusion: Slow inspiratory muscle training is not only effective in reducing resting BP, even in older people with well controlled isolated systolic hypertension but also increases inspiratory muscle strength, lung capacity and arm exercise duration.

1. Introduction

Isolated systolic hypertension (ISH), which becomes increasingly prevalent with advancing age, is difficult to control (Chobanian, 2007) and is a major risk factor for cardiovascular disease (Franklin and Wong, 2013). While there is a wide range of pharmacological treatments available it is generally acknowledged that exercise and life-style interventions play an important role in managing hypertension (Sharman et al., 2015) but many older people have painful arthritic joints or problems with balance making exercise programmes such as jogging, cycling or aerobic dance, unsuitable or unattractive. There are, however, a number of studies of slow breathing training which have proved very effective in reducing resting blood pressure (BP) as well as the responses to static exercise (Jones et al., 2010; Cernes and Zimlichman, 2015; Sangthong et al., 2016).

Another problem of old age that limits activity is deteriorating lung function (Lowery et al., 2013). The diaphragm becomes weaker, the chest wall less compliant and there is a loss of elastic recoil together with airway instability, all of which results in reduced lung expansion and a tendency towards hyperinflation during exercise (Vaz Fragoso and Gill, 2012; Skloot, 2017). Hyperinflation is uncomfortable, increases the work of breathing and discourages activity, thereby exacerbating the problems of physical inactivity, as occurs in the more extreme case of COPD (O'Donnell and Webb, 2008).

Inspiratory muscle strength training has been shown to increase inspiratory force and to improve exercise capacity both in young and

Abbreviations: AE, abdominal expansion; CE, chest expansion; CI, confidence interval; CON, control; IC, inspiratory capacity; HR, heart rate; ISH, isolated systolic hypertension; sBP, systolic blood pressure; dBP, diastolic blood pressure; PP, pulse pressure; MAP, mean arterial pressure; MIP, maximum inspiratory pressure; SVC, slow vital capacity; SLB, slow loaded breathing

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

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older subjects, probably because the stronger inspiratory muscles are able to work at a lower percentage of their maximum force, reducing the perception of exertion as well as afferent feedback from the working muscles (McConnell, 2012). Inspiratory muscle training may be particularly relevant to the problems of upper body activity experienced by many older people and those with respiratory deficiency since during arm exercise intercostal and accessory respiratory muscles act to stabilize the arms and torso, limiting chest wall expansion and thus increasing the work of the inspiratory muscles (Martinez et al., 1991; Mackey et al., 1998; Hodges and Gandevia, 2000; Cerny and Ucer, 2004).

The majority of studies using slow breathing training to reduce hypertension simply regulate breathing frequency without imposing a load (Cernes and Zimlichman, 2015). However, we have previously used a threshold inspiratory training device and found that a load of 18–20 cmH_2O, or approximately 20% maximum inspiratory pressure (MIP), was more effective than training with no inspiratory load in reducing blood pressure, and particularly systolic blood pressure (Jones et al., 2010; Sangthong et al., 2016).

A breathing training programme that resulted in a reduction in blood pressure, an increase in inspiratory muscle strength, lung capacity and arm exercise endurance would be of considerable advantage to older people. However, the training loads used for most inspiratory muscle training (IMT) studies are generally 50–60% MIP (Romer et al., 2002), and it is not known whether the low load that we have previously used for blood pressure reduction would be sufficient to improve lung function.

Consequently, the aim of the present study was to determine whether a breathing training programme which was primarily designed to reduce blood pressure using a relatively low load has the additional advantage of improving lung function and arm exercise tolerance in older people with isolated systolic hypertension.

2. Methods

2.1. Participants

Older people with ISH were recruited from primary care units in the local community and the hypertension clinic between April and September 2016, by one of the investigators (PT). Inclusion criteria were: age 60 to 80 years with controlled mild to moderate ISH, defined as resting systolic blood pressure (sBP) > 140 mm Hg and diastolic blood pressure (dBP) < 90 mm Hg (Chobanian et al., 2003) at the time of diagnosis, being independently active and with good communication. Exclusion criteria were secondary hypertension, use of beta-blockers, heart or respiratory disease and arm exercise limited by pain. The study was approved by the local Research Ethics Committee and conformed with the Declaration of Helsinki. All subjects provided informed consent in writing. In total, 62 subjects were recruited, 30 were excluded for various reasons (see Fig. 1 and Table 1 for subject details).

2.2. Study design and interventions

The study was a controlled trial in which subjects were assigned using randomised block allocation, stratified by sex, to either a slow loaded breathing training (SLB) group or a control deep breathing group (CON). A block size of 4 was used and allocation was decided by the patients drawing a sealed envelope. The study was single blind in as much as the participants were unaware of the expected outcome and were told that both treatments might be of benefit.

The study had two phases: a 2 week run-in followed by an 8 week training intervention (Fig. 1). Subject number was based on a very similar previous study (Sangthong et al., 2016) where significant changes were seen in resting blood pressure in the same type of patient with groups of 10 subjects; the sample size was increased in the present study with the expectation of seeing significant changes in dBP.

The SLB group trained with a load of 25% MIP using a BreatheMAX device as previously described (Sangthong et al., 2016) with the respiratory rate controlled at 6 breaths per minute with an inspiratory time of 4 s and expiratory time of 6 s. The CON group was instructed to use just deep breathing. Both types of training were undertaken at home with a total of 60 breaths a day, every day for 8 weeks.

The participants were given written instructions and taught how to measure heart rate and blood pressure at home and record the values in a training diary.

2.3. Measurements and data collection

Systolic, diastolic blood pressure and heart rate (HR) were measured at home with a digital oscillometric blood pressure monitor (Riester, ri-championN, Jungingen, Germany), using an appropriately sized upper arm cuff, every morning before 9.00 am in a sitting position after resting for least 5 min and refraining from caffeine or physical activity for the previous 30 min. HR and BP data were noted in a diary, together with a record of training, during the 2 week run-in and the following 8 week training period. Subjects were contacted by telephone once a week and visited at home every 2 weeks when data from the blood pressure monitors were downloaded.

Laboratory measurements of HR, BP, respiratory function, together with an exercise test, were carried out in the laboratory before and within 5 days of the end of training. On arrival at the laboratory subjects rested in easy chair for at least 15 min before resting measures of HR, BP and respiratory frequency were made. The procedures for respiratory function measurements followed standard guidelines (American Thoracic Society/European Respiratory Society, 2002) and were made by the same operator (PT) throughout the study. Reliability was evaluated with repeated measurements of 10 healthy subjects (5 male and 5 female) with intraclass correlations of 0.90, 0.95, 0.97, 0.97 and 0.98 for, respectively, MIP, slow vital capacity (SVC), inspiratory capacity (IC), chest expansion (CE) and abdominal expansion (AE).

Respiratory rate (RR) was measured with a plethysmography transducer (Biopac™ SS5LB; Biopac system Inc., USA) as chest movement at the level of the xiphoid process. The signal was recorded and averaged over 15 min with the subject sitting at rest and then recorded every minute during exercise.

Maximal inspiratory pressure. Inspiratory muscle strength was measured as MIP (Micro RPM, Micro Medical, Inc., Chatham Maritime, Kent, UK).

Spirometry testing. SVC and IC were measured using a portable computerized spirometer (KoKo spirometer, PDS Healthcare Products, Inc., USA).

Chest wall and abdominal expansion. Chest wall expansion was measured at the level of the xiphoid process using an inextensible measuring tape with a controlled traction force of 10 N. The subject was seated on a chair, breathing normally for 3 breaths and then performed a deep expiration follow by a maximal inspiration. Abdominal expansion, while standing, was measured at a level half way between the xiphoid and umbilicus with the same method as chest wall expansion. Each expansion was measured 3 times and the maximum value recorded provided there was no more than a 5% difference between the highest two otherwise the measurements were repeated.

Exercise test. Subjects undertook an exercise test using an arm ergometer at 50% of heart rate reserve. To determine the appropriate load before the start of the study, subjects undertook a progressive exercise test until the target heart rate of 50% heart rate reserve, calculated from the resting HR and the maximum value estimated as 207-(0.7*age) (Gellish et al., 2007). This was used for constant load exercise testing to volitional fatigue on a second (pre-training) visit and again at the end of the 8 weeks training period. The ECG signal was recorded from limb lead II connected to the MP36 BIOPAC system (BIOPAC System, Goleta, CA, USA) and HR determined from the R-R interval, analysed using the MP36 BIOPAC system.