Breathing training improves sleep and cardiovascular health in Obstructive Sleep Apnea

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ABSTRACT

Obstructive sleep apnea (OSA) is a disease defined by airflow limitations (hypopneas) and/or complete obstructions (apneas) throughout the night, and severity is indicated by the number of events per hour of sleep or apnea hypopnea index (AHI). OSA patients experience disrupted sleep and are at greater risk for hypertension, cardiovascular disease, and stroke. Unfortunately, the gold-standard of treatment for OSA, continuous positive airway pressure (CPAP), has discouraging compliance rates. Here, we report on inspiratory muscle strength training (IMST) as a potential new treatment for OSA. Mild-moderate sleep apnea patients underwent six-weeks of IMST. Training consisted of 30 breaths daily, for 6 weeks, using a take-home inspiratory resistance device (POWERbreathe® K3 series). Subjects were randomly assigned to a treatment group: training (75% of maximal inspiratory pressure (PI_{max})) or placebo (15% of PI_{max}). Pre- and post-assessment measures included: overnight polysomnography (PSG), Pittsburgh sleep quality index (PSQI), spirometry, blood pressure, and PI_{max}. We find individuals in the training group exhibit reductions in PSQI scores (11.0±0.9 vs. 6.0±1.4, pre-post) relative to placebo (10.0±1.1 vs. 9.9±0.7, pre-post). Additionally, individuals in the training group exhibit pre-post reductions in systolic and diastolic blood pressures (131.5±3.1/83.5±2.7 vs. 121.6±2.5/77.4±1.3) relative to placebo (129.8±4.8/80.6±3.1 vs. 131.9±5.0/84.6±2.7). We saw no change in AHI, however PSG results show reductions in periodic limb movement indices in training subjects (32.4 vs. 15.6, pre-post) relative to placebo (11.7 vs. 13.8, pre-post). Individuals in the training group also show improvements in the proportion of time spent in non-REM sleep (70.7% vs. 77.2%, pre-post) relative to placebo (72.0% vs. 74.6%, pre-post). In summary, individuals undertaking 6 weeks of IMST show improvements in: perceived sleep quality, proportion of consolidated sleep time, periodic limb movements, and systolic and diastolic blood pressures when compared to individuals in a placebo group. These results support IMST as a treatment that can improve the cardiovascular and sleep quality parameters in individuals with mild-moderate OSA.

METHODS

Assessment measures:

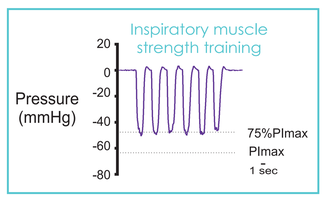
Weekly measures:
- ⋆Maximal inspiratory pressure (PI_{max})
- ⋆Spirometry
- ⋆Blood pressure
- ⋆Heart rate, SaO_2, breathing rate, PET_{CO2}, airflow, tidal volume during a 2 minute rest period

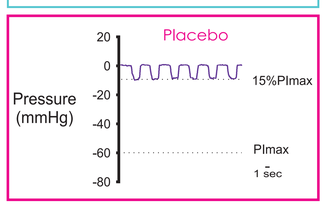
Pre-Post measures:
- ⋆Overnight polysomnography (PSG)
- ⋆Pittsburgh sleep quality index (PSQI)
- ⋆Height
- ⋆Weight

POWERbreathe®

Training protocol:
- ⋆Subjects performed training every day for six weeks.
- ⋆Training comprised 5 sets of 6 breaths (30 breaths total) per day.
- ⋆At the end of each week the subject came into the laboratory for re-assessment of maximal inspiratory pressure and resetting of their training device.

Two groups:
- ⋆Inspiratory muscle strength training (IMST): individuals in this group trained at 75% PI_{max}
- ⋆Placebo: individuals in this group trained at15% PI_{max}





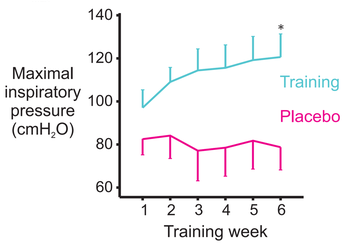


Figure 1. Sample IMST training sessions and weekly maximal inspiratory pressure (PI_{max}).
Left: Representative (intra-oral) pressures recorded during IMST and placebo training sets.
Right: Average PI_{max} per week of training. Note the steady increase in PI_{max}, a measure of inspiratory muscle strength, in the IMST trained individuals. Individuals in the placebo group showed no change. (** P<0.05, pre- vs. post-training)*

RESULTS

Table 1. Average data by treatment group, pre- vs. post-training. Mean ± SE values for age, weight, height, neck circumference, and BMI for each treatment group. Also given: average values for systolic blood pressure (SBP), diastolic blood pressure (DBP), and Pittsburgh sleep quality index (PSQI).
(P<0.05, pre- vs. post-training)*

Treatment group	Age (yrs)	Weight (kg)	Height (cm)	Neck circ. (in)	BMI	SBP (mmHg)		DBP (mmHg)		PSQI (0-21; <5 norm)	
						Pre	Post	Pre	Post	Pre	Post
Training	53.2±5.6	91.1±4.3	181.4±3.1	16.0±0.5	27.6±0.6	131.5±3.1	121.6±2.5*	83.5±2.7	77.4±1.3	11.0±0.9	6.0±1.4*
Placebo	61.5±5.0	84.1±7.7	166.8±2.3	16.0±0.7	30.0±2.5	129.8±4.8	131.9±5.0	80.6±3.1	84.6± 2.7	10.0±1.1	9.9±0.7

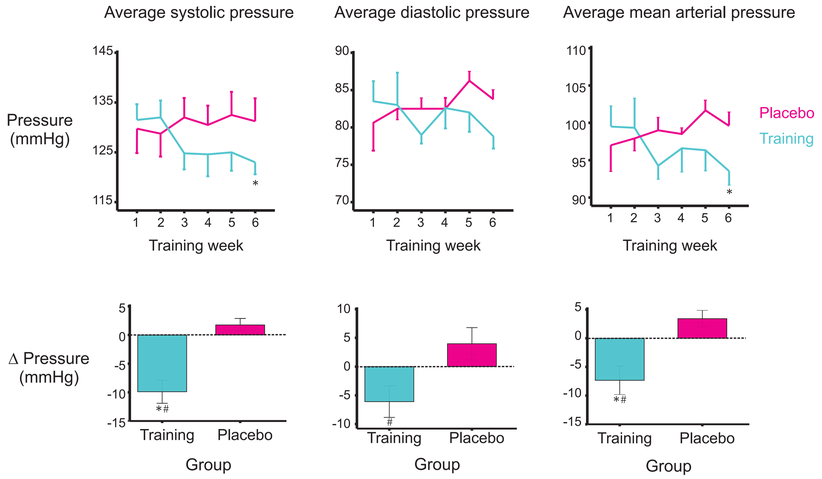


Figure 2. Systolic, diastolic, and mean arterial blood pressure.
Upper Panel: Weekly blood pressure. Note the steady decline in SBP, DBP, and MAP over the course of the 6 week IMST program. The placebo group showed no significant change in BP.
Lower Panel: Change in blood pressure, pre- vs. post-training. Individuals in the training group showed an average change in SBP, DBP, and MAP of -9.9, -6.6, and -7.33, respectively. Individuals in the placebo group showed an average change in SBP, DBP, and MAP of +2.1, +4, and +3.4, respectively.
*(*P<0.05, pre- vs. post-training; # P<0.05, training vs. placebo)*

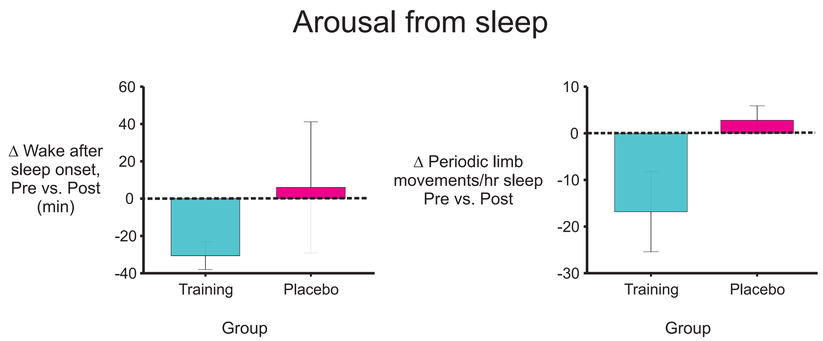


Figure 3. Change in wake after sleep onset (WASO) and periodic limb movements (PLMs), pre- vs. post-training. Following six weeks of breathing training, individuals who completed IMST exhibited a reduction in WASO and PLMs, pre- vs. post-training. Individuals in the placebo group showed no change in either measure. (Teal = IMST training; Pink = placebo training)

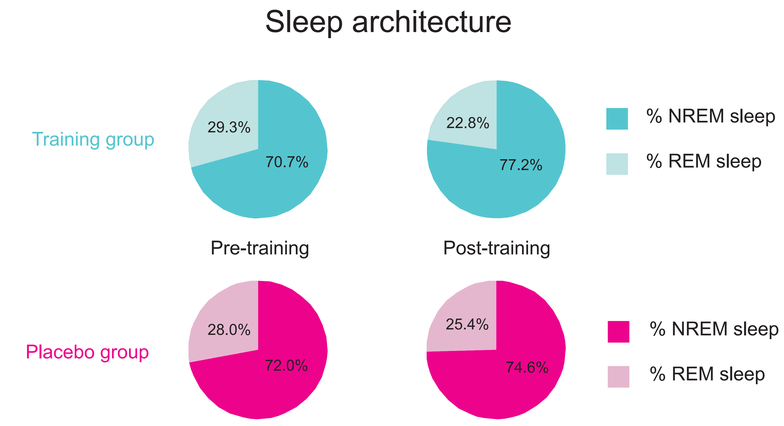


Figure 4. Percentage of REM and non-REM sleep. Percentage of sleep time spent in REM and NREM. The training group demonstrated a 9.2% improvement in NREM (consolidated) sleep. The placebo group showed a 3.6% increase in NREM sleep.

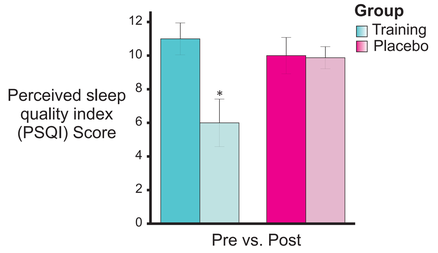


Figure 5. Change in perceived sleep quality pre-post training. Perceived sleep quality index (PSQI) scores pre- vs. post-training. Scores range from 0-21, where 0-5 is considered a normal range. Note the significant improvement in PSQI scores for the training group following 6 weeks of IMST. The placebo group showed no change.
(P<0.05, pre- vs. post-training)*

CONCLUSIONS

- ⋆ Six weeks of IMST improved systolic and diastolic blood pressure in OSA patients, relative to a placebo group of OSA patients.
- ⋆ Patients in the training group showed improvements in arousals from sleep and percentage of time in consolidated sleep. We suggest that these improvements result in the observed improvements in perceived sleep quality.
- ⋆ Although AHI was unaffected, our six week intervention was successful in improving the cardiovascular and sleep sequelae of OSA. In this way, IMST may serve as a supplementary intervention to conventional OSA treatments.
- ⋆ The training takes approximately 5-10 minutes to complete, once daily with a hand-held, commercially available device. As common blood pressure medications often only reduce BP by 2-5 mmHg, our non-pharmaceutical intervention has much potential.
- ⋆ Future studies aim to investigate the mechanism(s) involved in this treatment effect. Specifically, sympathetic nerve recordings and plasma inflammation will be assessed pre- and post-treatment.

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