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Title: Efficacy of respiratory muscle training as a practical and minimally intrusive technique to aid functional fitness among adults with obesity.

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Running head: Respiratory muscle training and obesity

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ABSTRACT

Objective: To examine the efficacy of respiratory muscle training (RMT) as a non-intrusive and practical intervention to stimulate improved functional fitness in adults with obesity. As excess adiposity of the chest impedes the mechanics of breathing, targeted re-training of the respiratory muscles may ameliorate sensations of breathlessness, improve physical performance and lead to greater engagement in physical activity.

Methods: Sixty seven adults (BMI = 36 ±6.5) were randomized into either an experimental (EXP: n=35) or placebo (PLA: n=32) group with both groups undertaking a 4-week RMT intervention, comprising daily use of a proprietary inspiratory resistance device set to 55% (EXP), or 10% (PLA) of maximum inspiratory effort.

Results: Respiratory muscle strength was significantly improved in EXP (19.1 cmH_20 gain; $P<0.01$) but did not change in PLA. Additionally, the post training walking distance covered was significantly extended for EXP ($P<0.01$), but not for PLA. Bivariate analysis demonstrated a positive association between the change (%) of performance gain in the walking test and BMI ($r = 0.779$; $P<0.01$) for EXP.

Conclusion: The findings from this study suggest RMT provides a practical, self-administered intervention for use in a home setting. This could be a useful strategy for wider scale public health implementation and concurrent application of physical activity initiatives.

Key words:

Obesity, physical activity, respiratory disorders, chronic disease

INTRODUCTION

Adults with obesity commonly experience shortness of breath at rest and during exercise compared to healthy normal weight adults.[1-5] This is typically due to excess adiposity of the chest which impedes the actions of the respiratory muscles, leading to an inability to exercise effectively and is associated with conditions such as obesity hypoventilation syndrome and sleep apnea.[6-7] As physical inactivity exacerbates breathing inadequacy by detraining respiratory and skeletal muscles,[2-3,8] the primary purpose of this study was to examine whether or not a respiratory muscle training (RMT) programme undertaken in a home setting might both strengthen the muscles of respiration of adults with obesity and thereby increase their capacity to performance exercise.[9-10] The application of such an unintrusive, self-administered and practical intervention might prove a meaningful public health intervention for wider scale implementation. Improved performance of detrained respiratory muscles in people with obesity would be expected to enable greater capacity to engage and perform exercise through improvements to breathing, [5] but as yet only a single pilot study has examined this issue among out-patients [11] although, encouraging gains have been demonstrated among athletic groups.[8]

Many physical activity interventions have been developed which aim to improve health outcomes for adults with obesity by reducing excess body weight. [2] However, the effectiveness of exercise is often restricted by factors associated with premature fatigue, such as breathlessness. [3-4] Such sensations of fatigue could diminish the motivational drive to commence a physical training programme or affect the sustainability of participation.[12-13]

The act of inspiration is the primary cause of work when breathing. This occurs whereby the chest and lungs expand to accommodate an increased volume of air, while expiration is largely passive, particularly when resting or only exercising at moderate intensity.[14] Consequently, a pre-exercise training programme specifically designed to enhance the performance of inspiratory muscles for adults with obesity might lessen subconscious inhibition of exercise performance, [15] reduce respiratory muscle fatigue [4] and promote improved performance in response to exercise challenges. [8,16] In support of this perspective, a recent study of hospitalized obese adults demonstrated an aggressive two month intervention of supervised respiratory (inspiratory and expiratory) muscle training coupled with diet and physical training significantly improved both respiratory muscle endurance and the distance covered in a 6-minute walking test (~11% gain).[2] While the results of that experiment strongly suggest respiratory muscle training may be of value to obese individuals, its findings are not directly applicable to non-hospitalised individuals due to the multidimensional nature of the intervention and the supervisory requirements of such an intense protocol. A less aggressive, but potentially equally effective strategy, is via inspiratory muscle training (RMT) using a portable inspiratory-resistance training device. [8-9,11,16]

The RMT strategy proposed in this study is minimally intrusive, does not require supervision and directly targets inspiratory effort which account for ~80% of the work of breathing at rest.[14] This strategy has been shown to improve inspiratory muscle strength and physical performances across a range of individuals in as little as four weeks. [8-9, 11,16] Performance gain in response to RMT could support this technique as an important priming (preparatory) strategy for overweight and obese individuals prior to prospective entry in a physical training programme.

As obese individuals are well known to experience shortness of breath to a greater extent than healthy normal subjects [4] it is therefore likely that a programme of RMT training will be particularly meaningful for obese individuals. The aim of this study is therefore to investigate whether a programme of RMT will improve inspiratory muscle strength and functional performance as assessed by the self-paced 6-minute walk test. [17]

METHODS

Participants

Sixty seven adults (37 males and 30 females) volunteered for this study, provided written informed consent prior to participation and were randomly allocated to either experimental (EXP: *n*=35; m=19, f=16) or placebo (PLA: *n*=32; m=18, f=14) group as matched parallel pairs based on body mass index (BMI) and history of smoking. Inclusion criteria were (i) BMI >27 kg/m^2 and (ii) being free of respiratory or cardiovascular diseases. The physical characteristics of the two groups are shown in Table 1. Ethical clearance for this study was provided by the Research and Ethics committee of James Cook University.

Study Overview

Baseline physical assessments were made of mass, height, blood pressure, standard spirometry (FVC, FEV_1), inspiratory muscle pressure (MIP), 6-minute walk test performance and estimation of maximal aerobic power ($\dot{V}O_2$ max). Following these measures, all individuals undertook familiarization with a proprietary portable inspiratory-resistance training device (PowerBREATHE, UK). This device was pre-set to either 55% of individualized maximal inspiratory effort (EXP) or to the minimum device setting equivalent to approximately 10% of maximal inspiratory effort (PLA) and thereafter used during the experiment. [8-9] Over the 4-week period, both groups performed 2 x 30 daily inspiratory efforts [15-16]. The assessments were then repeated following the 4-week intervention. Adherence and compliance to the training protocol were regularly checked and no participants reported experiencing issues or difficulties.

Study procedures

Lung function and inspiratory muscle performance

Spirometry measurements (Microlab-Spirometry SN M20364, USA) were undertaken at baseline and repeated post-programme. These included forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV_1) .

In addition to standard spirometry measures, maximal static inspiratory mouth pressure (MIP) was also measured. This was assessed at residual volume following a slow and complete expiration using a mouth pressure meter (PowerBREATHE KH1 INSPIRATORY METER, Gaiam, UK). The best of three maximal efforts were analysed for all measures. These procedures were completed similarly with our earlier methodology.[8-9, 11]

Functional exercise capacity

Participants were instructed to "*walk as far as you can in six minutes without running or jogging*" in accordance with previously validated techniques for a 6-minute walk test test.[17] Distance covered (m) and heart rates were recorded at the conclusion of the 6-minute period. This test is a clinically relevant and common procedure which provides an effective measure of functional walking capacity in untrained, sedentary adults. [17-19]

Using a validated heart rate derived algorithm, maximal aerobic power ($\dot{V}O_2$ max) was estimated from a sub-maximal single stage 4-minute walking test.[20] All participants were requested to perform an individually determined brisk and constant walking pace ranging from 3.5 to 5 km/h for 4-minutes on a treadmill in accordance with the protocol.

The study participants were required to wear a heart rate watch and a chest strap transmitter (Polar, T31 Coded Transmitter, Australia) during exercise testing.

Psychological measures

The CR10 Borg Scale was used to ascertain ratings of perceived exertion RPE as an index of fatigue perception in response to exercise. [21]

Statistical analyses

Statistical software package SPSS (version 18.0, SPSS, Chicago, Illinois) was used for all statistical analyses. Parametric pre- and post-training results and group interactions were statistically compared using two-way repeated measures analyses of variance (group x time) (ANOVA). Where differences were indicated, post hoc Tukey tests of Honestly Significant Difference were used to compare means. Associations between data sets were examined using Pearson Product Moment Correlations. To ascertain an appropriate sample size for the study, analysis was based on an anticipated mean improvement (SD) in the six minute walk test of ? in the EXP compared with the PLA group [8]. Probability values of <0.05 were considered significant and all tests were two sided. All results are expressed as means (SD) unless otherwise stated.

RESULTS

Evaluation of distance covered in response to the 6-minute walking test revealed a significant group x time ANOVA interaction. As expected, there was no difference between groups at baseline, post-hoc within-group comparisons for time (pre- to –post-training) indicated EXP significantly improved distance covered (m) in response to the 6-minute walk test from baseline to post-training (60.6 ±25.7 m gain; $P<0.01$). Conversely, the distance covered by PLA was not significantly extended over the 4-week intervention period (13.3 ±35.9 m gain; NS).

***** FIGURE 1 HERE *****

The estimation of $\dot{V}O_2$ max in response to treadmill walking did not identify a significant difference between EXP and PLA at either baseline or after the intervention (Table 2). Additionally, assessment of standard spirometry variables (FVC and FEV_1) also did not identify differences between groups at either baseline or post-training (Table 2).

The MIP assessment revealed a significant group x time ANOVA interaction effect ($P<0.01$). Subsequent post hoc Tukey HSD test evaluation demonstrated MIP improved significantly over the 4-week intervention for EXP (19.1 ±18.5 cmH_2O gain; $P<0.01$). However, MIP did not significantly change for PLA (9.3 ±7.1 cmH_20 gain; NS). There was a between group difference following the intervention where EXP demonstrated significantly greater MIP than PLA ($P<0.01$).

Heart rate responses to the 6-minute walk test were unchanged for both EXP (123.5 ±14.1 and 120.5 ±15.4 b/min) and PLA (118.1 ±14.6 and 116.4 ±11.3 b/min) from pre- to post-training.

RPE evaluations undertaken after exercise were not different between groups and did not change significantly from baseline to post-training in either EXP (2.71 ± 0.7 to 2.66 ± 0.8) or PLA (2.69 ±1.7 to 2.97 ±1.8).

A significant correlation between % change of distance covered in the 6-minute walk test (pre- to post-training) was significantly associated with baseline BMI ($r = 0.779$; $P<0.01$). This effect between a participant factor and intervention response was specific to EXP. There were no meaningful associations identified in PLA.

DISCUSSION

The main finding of this study was that a 4-week period of inspiratory muscle training (RMT) appears efficacious for improving respiratory muscle strength and the functional walking fitness of obese and overweight participants. As these effects were not evident in PLA, it suggests that RMT may be a meaningful intervention with which to augment physical performance outcomes for overweight and obese individuals. The results of our study support and exceed those from our earlier pilot data [11] and also from hospitalized obese individuals. [2] As these results were achieved with a considerably less aggressive intervention it seems likely that such a practical technique undertaken in a home setting might be suitable for larger scale public health initiative which confirms earlier small-scale pilot findings.[11]

Several mechanisms by which RMT evokes performance improvements have been proposed to explain the positive effects of RMT. These include delayed fatigue of the respiratory muscles, [22] a greater redistribution of blood flow from more efficient respiratory muscles to skeletal muscles [23] and reduced sensations of respiratory and limb discomfort in response to exercise. [24-25] As alterations to the functionality of respiratory muscles therefore appear to affect interactions between the brain and working locomotor muscles, [13,26] it is likely that RMT-induced improvements to inspiratory muscle performance would benefit this feedback mechanism. This may desensitize subconscious recruitment patterns of working skeletal muscles as a consequence of reduced sensations of breathlessness during physical activity. In our study, post-test evaluations of perceived exertion suggest individuals paced themselves according to physical sensations, such as a tolerable level of physical discomfort the individuals were prepared to endure in the 6-minute task.[12-13] As such, participants would (and did) experience the same level of tolerable physical discomfort during the 6-minute walk test at both baseline and post-training. The difference would therefore not be evident in a change to the perceived exertion but in a changed (improved) outcome of greater distance covered. Consequently, this is consistent with the greater distance achieved post-training for EXP for the same level of physical discomfort compared to baseline.[13]

Bivariate analysis revealed an interesting association between data sets whereby the (%) change from baseline to post-training in distance covered for the 6-minute walk test was positively related to BMI for EXP ($r = 0.779$; $P<0.01$). This suggests individuals of higher BMI could gain the most from an RMT intervention as greater adiposity of the chest wall increases respiratory resistance and sensations of dyspnea. [27]

MIP results for EXP remained beneath levels reported for healthy subjects [9,16] suggesting that continuation of RMT beyond a 4-week period could be meaningful to an obese population where detraining effects may be substantial. There are very limited data in this topic area and therefore, further studies may elucidate whether extending RMT prior to physical training and also concurrent (RMT and physical) training strategies improve performance outcomes for overweight and obese individuals.

There were several limitations to this study, which although much larger and robust than our previous pilot study did not include a concurrent RMT and exercise intervention. The use of RMT in parallel to an exercise training intervention could be expected to augment adaptations from this report in which RMT was purely used an intervention alone. A 4-week period of RMT demonstrates the usefulness of the technique is a short period, but a longer intervention would further demonstrate whether training effects are sustainable, subject to plateau or decreased motivation.

This study demonstrates new evidence that gains in functional fitness are achievable following a minimally intrusive RMT intervention among people with obesity. It is possible that such a targeted inspiratory muscle intervention could form part of a public health strategy to improve the exercise engagement and compliance among people with obesity.

In summary, RMT may provide a practical, minimally intrusive intervention to augment both inspiratory muscle strength and walking distance among overweight and obese adults. The beneficial effects of this treatment were similar to those previously reported from vigorous, supervised training among hospitalised obese patients.[2] Our findings indicate similar effects could be expected without the need for hospitalisation and indicate that RMT via an inspiratory resistance device can easily be performed in the home environment. Therefore, RMT appears a useful strategy to enhance walking performance in overweight and obese individuals which may prove a meaningful priming (pre-exercise) intervention with which to stimulate performance adaptations and future engagement with physical activity.

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Disclosure:

None of the authors had a conflict of interest regarding any aspect of this work.

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Figure captions:

Figure 1. Distance covered (metres) in response to the 6-minute walk test for both experimental (EXP; n=35) and placebo (PLA; n=32) groups. * = significant difference between baseline and post-training distance covered ($P<0.01$). Means ±SD and individual (before and after training) results are displayed.