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Effects of inspiratory muscle training on respiratory function and repetitive sprint performance in wheelchair basketball players

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ABSTRACT

Background: There is considerable evidence that respiratory muscle training improves pulmonary function, quality of life and exercise performance in healthy athletic populations. The benefits for wheelchair athletes are less well understood. Therefore, the present study examined the influence of inspiratory muscle training (IMT) upon respiratory function and repetitive propulsive sprint performance in wheelchair basketball players.

Methods: Using a placebo-controlled design, 16 wheelchair athletes were divided to an experimental (IMT; n=8) or placebo (sham-IMT; n=8) group based upon selective grouping criteria. The IMT group performed 30 dynamic breaths, twice daily at a resistance equivalent to 50% Maximum Inspiratory Pressure (MIP) and the sham-IMT group performed 60 slow breaths once a day at 15% MIP for a period of 6 weeks.

Results: The IMT group improved both MIP and MEP (17%, 23% respectively; $p \leq 0.03$). Similar improvements were noted for the sham-IMT group with 23% and 33% from base-line for MIP and MEP respectively ($p \leq 0.03$). There were no significant changes in pulmonary function at rest and any of the performance parameters associated with the repetitive sprint test (sprint and recovery times, HRpeak and peak blood lactate concentration). Reported experiences of using the IMT training device suggested 'less breathlessness' and 'less tightness in the chest during the training'.

Conclusions: Although there was no improvement in sprint performance, participants in both the IMT and sham-IMT reported an improved respiratory muscle function and quality of life.

INTRODUCTION

It has been found that inspiratory muscle training (IMT) among able-bodied athletes increases respiratory muscle strength, delays respiratory muscle fatigue and the onset of breathlessness. [1-7] Respiratory muscle training has proven to be beneficial for respiratory function in patients with chronic diseases [8-11] and patients during the early rehabilitation stages of spinal cord injury. [12] To date, in terms of disability athletic populations, then only one study using a slightly different training method to IMT, investigated the benefits of respiratory muscle endurance training (RMET) in athletes with paraplegia. [13] In that study, [13] significant improvements were found in respiratory muscle endurance after 6 weeks of RMET, but not in 10 km performance. No research has investigated whether these noted benefits are transferable to wheelchair games players, using methods similar to the work of Romer and co-workers[4] who found improvements in the recovery time of able-bodied athletes during high intensity and intermittent exercise. Interestingly, along with those wheelchair sports of a repetitive sprint nature, this type of exercise seems to correspond much better to daily life activities of the general wheelchair user.

Wheelchair basketball is a popular team sport for wheelchair users with paraplegic conditions that include spinal cord injury, spina bifida and poliomyelitis. These disabilities generally affect the lower limbs of the body but depending on the severity of the disorder and the level of the lesion can also affect the upper limbs and the respiratory system. Since normal respiratory function involves the respiratory musculature of chest, back and abdominal area this could account for the feelings of dyspnea in wheelchair athletes compared with able-bodied counterparts during the same duration and type of exercise.[14] Accordingly, the purpose of this study was to examine the effects of IMT training upon the quality of life / respiratory function and repetitive propulsive sprint performance in wheelchair basketball players.

MATERIALS AND METHODS

Participants

This study was approved by the local University Ethics Committee and participants' informed consent was obtained prior to data collection. Sixteen competitive wheelchair basketball players participated in the study. The disabilities of the participants included spinal cord injury (SCI), post polio and spina bifida, the minimum time of onset of disability was five years. The descriptive characteristics of the participant groups are presented in Table 1. All participants were highly trained and competed regularly in wheelchair basketball competitions at a National level of above for at least four years. In addition to basketball specific training, other sporting activities included swimming, weight training and tennis with a minimum weekly activity of 10 hours. All but one participant were non-smokers (self-reported).

General design and procedures

Participants were divided by gender, ranked according to first their baseline maximum inspiratory muscle strength (MIP) and secondly the International Wheelchair Basketball Federation (IWBF) classification and then assigned to either an experimental (IMT) or placebo (sham-IMT) group using an ABBA grouping technique to ensure that no difference in MIP at base-line between the two groups existed.

Testing took place during the closed season. However, all participants were still completing their normal training programme. To prevent possible bias related to circadian rhythms each test was scheduled at the same time of day, at the same regular training session. Participants were advised not to take part in vigorous exercise during the two days before the tests and did not exercise on the day of the tests. All lung function tests were completed in the participants' 'every-day' wheelchair while sprints were completed in their 'basketball' wheelchair. To complete the lung function tests all participants sat up straight, without straps to prevent bias related to differences in posture and the disposition of the abdomen, respectively.

Table 1. Characteristics of participants in Inspiratory muscle training (IMT) and sham-IMT groups (mean ± SD); IWBF: International Wheelchair Basketball Federation.

		IMT	sham-IMT
Age (yrs)		28 ± 5	30 ± 11
Gender	Male	4	4
	Female	4	4
Level of Play	International	7	4
	National (Club)	1	4
Self reported smoker		0	1
Disability	SCI	6	7
	Polio	1	0
	Spina bifida	1	1
IWBF Basketball Classification	1/1.5	6	6
	2/2.5	1	1
	3	1	1

Pulmonary function

Forced vital capacity (FVC), forced expiratory volume in one second (FEV_1) and the maximum voluntary ventilation during 12s (MVV_{12}), were measured using a portable pneumotachograph spirometer (Vitalograph Gold Standard 2150, Buckingham, England). Peak expiratory flow (PEF) was measured using a hand-held peak-flow meter (Mini-Wright, Harlow, England). Measurements were made according to recommendations of the European Respiratory Society. [15]

Respiratory muscle strength

Respiratory muscle strength was measured using a portable hand-held pressure meter (Micro Medical Limited, Rochester, Kent, UK). Each participant was assessed for maximum expiratory (MEP) and maximum inspiratory (MIP) pressures. Ten maximal efforts were performed at 30 s intervals from residual volume for MIP, or total lung capacity for MEP. In line with previous methodologies, the highest value was chosen to represent MIP and MEP. [4]

Repetitive wheelchair sprint performance

The experimental design was similar to that previously reported by Romer and colleagues [4] which consisted of fifteen 20-m sprints with the performance criteria being to maintain maximal sprint performance whilst taking as little rest as possible between sprints. In order to familiarise the participants, the warm up consisted of 5 x 20 m at a self-selected speed followed by three sprints with 30 seconds rest in between. Following this warm-up each participant completed fifteen 20-m sprints. Sprints were automatically timed to the nearest 0.01 second by an electronic timing system (MMU-Cheshire, UK). Total test time was recorded manually to the nearest 0.01 second with a stopwatch. Total sprint time (sprint-1 time plus sprint-2 time etc) and total recovery time (total test time minus total sprint time) were calculated for all sprints and each set of five sprints.

Heart rate was recorded using radio telemetry throughout the sprint test (Polar Sport Tester, Kempele, Finland). Immediately following the sprint protocol a capillary blood sample was taken from the earlobe for subsequent determination of blood lactate concentration (Arkray, Lactate Pro, blood lactate test meter, Japan).

Inspiratory muscle training

The IMT was completed with a Powerbreathe device (POWERbreathe®, IMT Technologies Limited, UK). After one week of IMT at level 1 of the device, the protocol for the following 5 weeks was given to each participant and the technique was watched for accuracy. The experimental group (IMT) performed 30 dynamic inspiratory efforts twice a day against a pressure-threshold load equivalent to 50% MIP, a pressure known to improve performance in healthy people.[16] Participants in this group were instructed to incrementally increase the load (quarter turn on the Powerbreathe) once 30 breaths became easy to complete. The placebo group (sham-IMT) trained with 60 slow breaths once a day equivalent to 15% MIP, a pressure known to induce only minimal changes, if any, in inspiratory muscle function in able-bodied people.[4] Groups were told they were completing a study to look at the differences between endurance (sham-IMT) and strength (IMT) training of the respiratory muscles and were therefore blinded to the real purpose of the study. Instructions were given to cease IMT 48 hours before the post-test and to return the completed physical activity and IMT diary. This diary enabled participants to write down their daily activities and their adherence to the training programme. Furthermore, a questionnaire was given to each participant on completion of all the tests to identify the personal feelings of using Powerbreathe.

Data Analysis

The SPSS 15.0 statistical package (SPSS Inc., Chicago IL, USA) was used for all the statistical analyses. Means and standard deviations were computed for all variables. A two-way analysis of variance with repeated measurements was used with as within-subject variable training (pre and post) and as between subject variable group (IMT vs. sham-IMT). Significance was assumed at $P \leq 0.05$. A Bonferroni *post hoc* test was applied to determine the location of any significant main effects.

Results

The participants for this study were representative of wheelchair basketball players who trained regularly, but yet had never used a Powerbreathe respiratory training device before. An important feature of the two groups was that they did have similar base-line MIP and MEP ($p > 0.05$).

IMT compliance: The self-reported diary sheets showed a 63 ± 13% adherence in the experimental group and 79 ± 19% adherence in the sham-IMT group. The participants were asked for their experiences of using Powerbreathe (Table 2). Of the 18 who completed the training, 75% said they would now buy a Powerbreathe and 83% said they felt that it would decrease the number and length of respiratory infections in the long term. “Less feelings of breathlessness” and “less tightness in the chest during the training” were familiar comments made in response to questions, indicating an improvement in the quality of life.

Table 2. Personal experience of using Powerbreathe.

Question	IMT		sham-IMT	
	YES	NO	YES	NO
1. Do you think it helped in every day life?	67%	33%	83%	17%
2. Do you think it helped on the basketball court or while doing any other physical activity?	83%	17%	83%	17%
3. Do you think it relieved some of the symptoms of being out of breath? Less tightness in the chest? Less heavy breathing?	83%	17%	67%	33%
4. Would you buy a Powerbreathe?	83%	17%	83%	17%
5. Do you think it could help long term in sports or every day life?	83%	17%	83%	17%

Pulmonary and Respiratory Muscle Function: For both groups, none of the pulmonary function measures were significantly changed following the training period (Table 3). However, significant improvements in MIP (75.4 ± 33.3 to 91.9 ± 25.5 cmH_20) and MEP (69.4 ± 21.0 to 84.5 ± 21.2 cmH_20) which corresponded to a change of 17% and 23% respectively, were noted for the IMT group. Interestingly, similar improvements were noted for the sham-IMT group with 23% and 33% improvements respectively from base-line for MIP (74.5 ± 27.3 to 87.5 ± 30.7 cm$H_2$0) and MEP (60.4 ± 18.3 to 79.6 ± 28.5 cm$H_2$0) (Figure 1). There were main effects for time, indicating a change from pre to post (MIP; p = 0.028 and MEP; p = 0.003). The non-significant group by time interaction (MIP; p = 0.776 and MEP; p = 0.667) showed that the changes were similar for the two groups.

Table 3. Inspiratory muscle training (IMT): n=8; sham-IMT: n=8. MVV: Maximum Voluntary Ventilation; FEV_1: Forced Expiratory Volume in one second; PEF: Peak Expiratory Flow. Mean ± SD.

	IMT		sham-IMT	
	Pre-IMT	Post-IMT	Pre-IMT	Post-IMT
FVC (L)	3.77 ± 0.60	3.77 ± 0.45	3.34 ± 1.23	3.41 ± 1.03
FEV_1 (L)	3.36 ± 0.70	3.39 ± 0.60	2.79 ± 1.05	2.90 ± 0.97
PEF (L.min^{-1})	492 ± 46	488 ± 39	448 ± 116	469 ± 109
MVV (L.min^{-1})	142 ± 41	158 ± 59	133 ± 48	137 ± 55

Repetitive Sprint Performance: Table 4 shows that neither IMT nor sham-IMT training resulted in changes in total test, sprint or recovery time ($p > 0.05$), or post blood lactate concentration ($p = 0.183$). Also the peak heart rate during the sprints was similar before and after training ($p = 0.521$), irrespective of the type of IMT training.

Table 4.Values are mean ± SD of performance tests pre and post Inspiratory Muscle Training (IMT) or sham-IMT training.

	IMT		sham-IMT	
	Pre-IMT	Post-IMT	Pre-IMT	Post-IMT
Total test time (s)	132 ± 10	131 ± 15	148 ± 25	149 ± 30
Total recovery time (s)	35 ± 12	40 ± 13	46 ± 27	47 ± 33
Peak HR (bpm)	181 ± 6	179 ± 8	172 ± 21	172 ± 18
Post blood lactate concentration (mmol.L^{-1})	9.0 ± 3.1	8.3 ± 3.5	6.9 ± 2.9	6.4 ± 2.5

Discussion

The primary finding of this study is that a 6-week period of IMT improves respiratory function and quality of life in wheelchair athletes. Interestingly the improvements in respiratory function occurred even after mild IMT training. This indicates that even minimal intensity IMT is sufficient to improve respiratory muscle function and quality of life in all disability groups tested.

Maximum respiratory pressures are temporarily reduced in people with high lesion spinal injuries but recover to some extent during rehabilitation. [10,12] Given that participants used a wheelchair for daily ambulation for several years it was considered that they all had a stable lung function. Since IMT predominantly concerns inspiration, most previous studies have focused on MIP rather than MEP. Nevertheless, significant increases have been found in MEP.[12-13] For spinal cord injury, the increased MEP may be an important factor contributing to the improved quality of life, as the increased ability to generate pressure will aid with coughing and normal respiration. Grandas et al, [17] noted that dyspnea in chronic SCI patients may be due to impaired ventilatory muscle function and that adaptive strategies are used to alleviate the problem.

The similar improvements in respiratory function in the IMT and sham-IMT groups may be related to the better adherence to the training programme shown in the sham-IMT group. Possibly, the effect of IMT training, whether strength or endurance focused was not due to stronger respiratory muscles, but a better technique/mechanical coordination or efficiency/learning effect of respiratory muscles. This might explain why both groups improved MIP and MEP by about the same amount. In this context, although not expected, the reason for an increase in MEP could be a mechanical advantage of respiratory muscles. If - due to IMT - subjects are able to inflate there lungs better (or different from a mechanical point of view), elastic recoil of the chest might be increased and thus also lead to a higher MEP value. These observations also highlight the need to closely control the adherence to training programmes in these groups.

We have shown that even minimal IMT would reduce symptoms of breathlessness during every day activities and exercise. In addition, in both groups, the participants felt the training would reduce the number and length of respiratory infections. Thus, overall IMT improved the quality of day-to-day life. Therefore, even mild IMT may be used successfully during the rehabilitation process of individuals with SCI to avoid respiratory infections and complications. However, to prove this assumption, further studies are needed. [10]

In line with previous observations in able-bodied subjects [7,18] we observed no significant improvement in sprint performance post IMT. It is quite possible that the large inter-individual variances in performance and the small sample size attributed to these non-significant findings. Moreover, it has been found that pre-fatigued respiratory muscles limit a subsequent exercise performance. [19] Hence, we could speculate that the time between the last respiratory training session and the sprint performance session (48h) was too short, and the respiratory muscles were still fatigued which may have influenced test results. This area warrants further investigation.

The main limitation of this study is the mixed disabilities in the present study population. Indeed, Van der Woude et al., [20] noted that aerobic capacity and respiratory function are highly variable upon disability and lesion level. It is thus advisable that future studies focus on a single disability and have the level of lesion in people with SCI as close as possible. The study is, however, indicative of the paraplegics within wheelchair basketball.

Conclusion

Our data indicates that the IMT, even at low intensity, had beneficial effects on respiratory function and quality of life. Future studies may address the question whether long-term respiratory muscle training would have lasting advantageous effects on respiratory muscle function and help decrease the severity of re-occurring chest and throat infections – a common illness of people with SCI.

What is already known on this topic: It has been found that inspiratory muscle training (IMT) among able-bodied athletes increases respiratory muscle strength, delays respiratory muscle fatigue and the onset of breathlessness. The benefits of this type of respiratory training has not be examined in wheelchair athletes.

What this study adds: This was the first time IMT was applied to investigate the impact of respiratory muscle training in highly trained wheelchair users. Despite no performance benefits, it was found that even mild respiratory training led to a better quality of life. This may imply that the benefit for the general population of SCI subjects should be even more pronounced.

References

1. Holm P, Sattler A, Fregosi RF. Endurance training of respiratory muscles improves cycling performance in fit young cyclists. *BMC Physiol 2004;* **4**,9.
2. Inbar O, Weiner P, Azgad Y, et al. Specific inspiratory muscle training in well-trained endurance athletes. Med Sci Sports Exer 2000; **32**, 1233-1237.
3. Lomax ME, McConnell AK. Inspiratory muscle fatigue in swimmers after a single 200 m swim. *J Sports Sci* 2003;**21**, 659-664.
4. Romer LM, McConnell AK, Jones DA. Effects of inspiratory muscle training upon recovery time during high intensity, repetitive sprint activity. *Int J Sports Med* 2002a; **23**, 348-352.
5. Romer LM, McConnell AK, Jones DA. Effects of inspiratory muscle training on time-trial performance in trained cyclists. *J Sports Sci* 2002b; **20**, 547-562.
6. Wells GD, Plyley M, Thomas S, et al. Effects of concurrent inspiratory and expiratory muscle training on respiratory and exercise performance in competitive swimmers. *Eur J Appl Physiol* 2005; **94**, 527-540.
7. Williams JS, Wongsathikun J, Boon SM, et al. Inspiratory muscle training fails to improve endurance capacity in athletes. *Med Sci Sports Exer* 2002; **34**, 1194-1198.
8. Mancini DM, Henson D, La Manca J, et al. Benefit of selective respiratory muscle training on exercise capacity in patients with chronic congestive heart failure. *Circulation* 1995;**91**, 320-329.
9. Sanchez Riera H, Rubio TM, Ruiz FO, et al. Inspiratory muscle training in patients with COPD: Effect on dyspnea, exercise performance and quality of life. *Chest* 2001;**120**, 748-756.

10. Van Houtte S, Vanlandewijck Y, Gosselink R. Respiratory muscle training in persons with spinal cord injury: A systematic review. *Respir Med* 2006; **100**, 1886-1895.

11. Weiner P, Azgad Y, Ganam R, Weiner M. Inspiratory muscle training in patients with bronchial asthma. *Chest* 1992;**102**, 1357-1361.

12. Liaw M-Y, Lin M-C, Cheng P-T, et al. Resistive inspiratory muscle training: its effectiveness in patients with acute complete cervical cord injury. *Arch Phys Med Rehab* 2000; **81**, 752-756.

13. Mueller G, Perret C, Hopman MTE. Effects of respiratory muscle endurance training on wheelchair racing performance in athletes with paraplegia: a pilot study. *Clin J Sports Med* 2008; 18, 85-88.

14. Wells CL, Hooker SP. The Spinal Injured Athlete. *Adapt Phys Act Quart* 1990; **7**, 265- 285.

15. Quanjer, PH, Tammeling, GJ, Cotes JE. et al. Lung volumes and forced ventilatory flows. *Eur Respir J* 1993; **6**, 5-40.

16. Caine MP, McConnell AK. Development and evaluation of a pressure threshold inspiratory muscle trainer for use in the context of sports performance. *Sports Engineer* 2000; **3**, 149-159.

17. Grandas NF, Jain NB, Denckla JB, et al. Dyspnea during daily activities in chronic spinal cord injury. *Arch of Phys Med and Rehabil* 2005*;* **86**, 1631-1635.

18. Morgan DW, Kohrt WM, Bates BJ, et al. Effects of respiratory muscle endurance training on ventilatory and endurance performance of moderately trained cyclists. *Int J Sports Med 1987;* **8**, 88-93.

19. Mador MJ, Acevedo FA. Effect of respiratory muscle fatigue on subsequent exercise performance. *J Appl Physiol* 1991; **70**, 2059-2065.

20. van der Woude LHV, Bouten C, Vegger HEJ, et al. Aerobic work capacity in elite wheelchair athletes: A cross sectional analysis. *Am J Phys Med Rehabil* 2002; **81**, 261-271.

Figure 1. The effects of 8 weeks IMT and sham IMT training on maximum inspiratory (MIP) and maximum expiratory (MEP) pressure for two separate groups of wheelchair athletes (total n = 16, mean ± SD). Note: * $p < 0.05$.