Exercise training and inspiratory muscle training in patients with Bronchiectasis

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ABSTRACT

**Background.** Bronchiectasis (BE) is a chronic suppurative lung disease often characterised by airflow obstruction and hyperinflation, and leading to decreased exercise tolerance and reduced health status. To date, the role of pulmonary rehabilitation (PR) and inspiratory muscle training (IMT) has not been investigated in this group of patients.

**Methods**
Thirty-two patients with idiopathic BE were randomly allocated to one of 3 groups: PR plus sham IMT (PR-SHAM), PR plus targeted IMT (PR-IMT), or control (CTRL). All patients (except CTRL) underwent an 8 week training programme of either PR or PR plus targeted IMT. Exercise training during PR was performed 3 times weekly at 80% of the peak heart rate. IMT was performed at home for 15 minutes, twice daily over the 8 week period.

**Results**
PR-SHAM and PR-IMT demonstrated significant increases in the Incremental Shuttle Walking Test (ISWT) of 96.7 metres (95% confidence interval 59.6 – 133.7 metres) and 124.5 metres (95% confidence interval 63.2 – 185.9 metres) respectively and in endurance exercise capacity of 174.9% (95% confidence interval 34.7 – 426.1) and 205.7% (95% confidence interval 31.6 – 310.6). There were no statistically significant differences in the improvements in exercise between the two groups. Significant improvements in inspiratory muscle strength (Pi max) were also observed both in the PR-IMT group (21.4cmH2O increase, 95% confidence interval 9.3 to 33.4; p=0.008) and the PR-SHAM group (12.0cmH2O increase, 95% confidence interval 1.1 to 22.9; p=0.04), the magnitude of which were also similar (p=0.220). Improvements in exercise capacity were maintained in the PR-IMT at 3 months after training, but not in the PR-SHAM group.

**Conclusions**
PR is effective in improving exercise tolerance in BE but there is no additional advantage of simultaneous IMT. IMT may, however, be important in the longevity of the training effects.
INTRODUCTION

Pulmonary rehabilitation is a multidisciplinary approach to treating patients with chronic lung disease and is advocated in American [1], British [2] and European [3] COPD guidelines as an important component of medical care. Since pulmonary rehabilitation has traditionally focussed on patients with COPD, its effectiveness in other chronic lung diseases has received little attention, although it has been implemented with clinical success in patients with Cystic Fibrosis [4] and those with restrictive pulmonary defects [5].

Bronchiectasis is a chronic (often suppurative) lung disease not traditionally included in the definition of COPD but also characterised by airflow obstruction and symptoms including cough, sputum production, wheeze, dyspnoea and decreased exercise tolerance [6, 7]. The causes of dyspnoea and the reduced exercise capacity are multifactorial and include altered pulmonary mechanics, inefficient gas exchange, decreased muscle mass and confounding psychological morbidity all of which lead to a progressive detraining effect [8]. Theoretically, one would therefore expect pulmonary rehabilitation to be as effective in Bronchiectasis as it is in COPD but to date only one previous study has been performed and included only 7 patients with the disease [9].

The reduced exercise capacity and increased dyspnoea in patients with COPD is partly attributable to expiratory flow limitation resulting in dynamic hyperinflation and increased intrinsic positive end-expiratory pressure, exacerbated by a reduction in inspiratory muscle force. Recently, Koulouris et al [10] demonstrated the presence of tidal expiratory flow limitation in patients with Bronchiectasis, related to an increase in dyspnoea and a reduced exercise tolerance. This was also postulated to be a result of dynamic hyperinflation and consequent inspiratory muscle loading.

Inspiratory muscle training (IMT) has been demonstrated to be an important adjunct to pulmonary rehabilitation in COPD patients with reduced respiratory muscle strength resulting in greater improvements in exercise capacity when compared to exercise training alone [11, 12]. This improvement in exercise capacity may be due to a reduction in the perception of dyspnoea during exercise, or be a result of the increase in inspiratory muscle strength at the end of the training programme [13]. The effect of inspiratory muscle training in conjunction with exercise training in patients with Bronchiectasis has not been investigated previously. However, the demonstration of inspiratory muscle loading during exercise [10] suggests that IMT may also be beneficial in this group of patients.

One of the hallmark symptoms of patients with Bronchiectasis is the chronic production of purulent sputum and the clearance of which may be improved by both physiotherapy [14], antibiotic therapy [15] and, in patients with Cystic Fibrosis, by exercise training [16]. Repeated inspiratory manoeuvres performed during specific inspiratory muscle training may potentially have a beneficial effect on ease of expectoration in patients with Bronchiectasis but this has not been investigated.

The aims of this study were therefore to compare the effects of pulmonary rehabilitation together with either targeted or sham IMT in patients with
Bronchiectasis. We assessed a range of outcome measures including respiratory muscle function, lung function, exercise capacity, sputum clearance and health status.
METHODS

Subjects
Thirty-two patients (6 male) with Bronchiectasis confirmed by High Resolution Computed Tomography (HRCT) were allocated randomly (using a computer generated random number sequence) to one of three groups: PR-SHAM - pulmonary rehabilitation plus sham inspiratory muscle training (n=11); PR-IMT – pulmonary rehabilitation plus targeted inspiratory muscle training (n=12); CTRL - control group, no intervention (n=9). In 18 of the patients studied the disease was confined to one or two lobes within the lungs. The remaining 14 patients had widespread disease that was either varicose or cylindrical in nature. Patients with HRCT evidence of concomitant emphysema were excluded from the study. Seven patients had previously undergone a lobectomy for their disease including 2 in the PR-IMT group, 3 in the PR-SHAM group and 2 in the CTRL group. In 23 patients the origin of the disease was unknown. In the remaining 9 patients the disease was attributed to a past childhood illness including pneumonia (n=5) and whooping cough (n=4).

During the training programme 1 patient withdrew from the PR-SHAM group and 1 from the PR-IMT group due to an exacerbation of the disease. During the subsequent follow up period a further 2 patients withdrew from each of the training groups, two of these were for personal reasons and the remaining 2 patients withdrew due to an exacerbation of their disease.

Patients were excluded if they had evidence of endocrine, orthopaedic or primary cardiac disorders, coronary artery disease, hypertension or cor pulmonale. Patients were also excluded if they had experienced an acute exacerbation within the previous 6 weeks or were receiving long term oral corticosteroid therapy. All other medications were permitted for use during the study. All patients were observed over a 4 week run-in period when their regular treatment was maintained, to verify stability in their clinical and functional status. The study protocol was approved by the South Birmingham Health Authority ‘Research Ethical Committee’.

Measurements
In the PR-IMT and PR-SHAM groups, measurements were performed at the start and at the end of the training programme (8 weeks) and 3 months after the programme had been completed. In the CTRL group measurements were performed on 2 occasions 8 weeks apart. All patients attended the laboratory prior to these study visits in order to familiarise them with the measurement procedures and therefore minimise the effects of test habituation. On this occasion measurements of respiratory muscle function were repeated until variability had decreased to less than 5% between manoeuvres and patients performed one test each of the maximal exercise test, endurance capacity test and the ISWT. Lung function tests were not practiced as all patients had previously performed these measurements on several occasions.

Lung function
Lung function testing was performed according to national guidelines [17] and included spirometry, static lung volumes, and transfer factor. Results were compared with standard reference values [18].
Respiratory muscle strength

Measurements were made according to the methods described by Black and Hyatt [19] using a handheld mouth pressure meter (Morgan Medical Ltd, Kent, U.K). Maximal expiratory pressure (Pe max) was measured near total lung capacity after a maximal inspiration; maximal inspiratory pressure (Pi max) was measured near residual volume after a maximal expiration. Pressures were maintained for at least one second and the highest of three technically satisfactory measurements (within 5%) was recorded.

Exercise testing

Exercise test conditions were standardised for time of day, medication administration, test instruction and degree of coaching. The endurance exercise test was performed on the same day as the incremental exercise test with a rest period of 1 hour. The incremental shuttle walking test (ISWT) was performed on a separate day.

(1) Maximal incremental treadmill test

Progressive exercise testing was performed on a treadmill (Morgan Medical Ltd, Kent, U.K) using a modification of the Balke protocol [20]. After initial recording of resting measurements (2 mins) the grade increased from an initial zero grade by a gradient of 1% each minute. During the test, continuous measurements were made of inspired ventilation (Vi), oxygen uptake (VO₂) and carbon dioxide output (VCO₂) and averaged over 30 second intervals. Ventilation (L/min) was measured by integration of the flow signal via a pressure transducer (Morgan Medical Ltd, Kent, UK) from a Fleisch pneumotachograph placed at the inspiratory port of a two-way non-rebreathable valve (Hans Rudolf, Cranlea, Birmingham, UK). Expired gas passed via a mixing chamber (Morgan Medical Ltd) and carbon dioxide (infra red analyser, Morgan Medical Ltd) analysers respectively. Heart rate and oxygen saturation were monitored throughout the test via a pulse oximeter (Ohmeda Biox 2700, Ohmeda, Herts, UK). At the termination of the test, end-exercise dyspnoea was rated using a modified Borg scale [21], peak oxygen uptake was recorded in ml/min/kg and compared to predicted values [22].

(2) Submaximal exercise test

Endurance exercise capacity was measured on a treadmill (Morgan Medical, Kent, UK) at 85% of the peak oxygen uptake achieved on the baseline incremental test. Patients exercised to volitional fatigue and the total distance walked in metres was recorded. Throughout the test, heart rate and oxygen saturation were continuously monitored via a pulse oximeter (Ohmeda Biox, Ohmeda, Herts, UK). The intensity of the endurance test was the same at the start and end of the training programme.

(3) Incremental shuttle walking test

Patients walked at an increasing speed up and down a 10m course delineated by two cones according to the methods of Singh et al [23]. The test was terminated when the patient was no longer able to maintain the required speed or became too breathless to continue, at which time the distance walked in metres was recorded.

Health status
Patients completed the St Georges Respiratory Questionnaire (SGRQ) [24] which included assessment in the three domains of symptoms, activities and impacts. Patients were blinded to their responses on previous visits in order to minimise bias after the training programme.

**24 hour sputum volume**
The patients began collection at a set time on the day preceding the scheduled visit and completed the collection period 24 hours later. Patients were encouraged to collect all expectorated sputum into pre-weighed containers and the volume collected was determined by weight, assuming 1g=1ml of sputum [25].

**PULMONARY REHABILITATION PROGRAMME**

*Exercise training*

Patients in the PR-SHAM and PR-IMT groups completed an 8 week hospital based outpatient programme of high intensity exercise training. Exercise training sessions were performed 3 times weekly and consisted of 2 sessions within the hospital and one further session being performed at home. The duration of each exercise training session was 45 minutes and patients were required to exercise at 80% of the peak heart rate achieved on the initial maximal incremental exercise test targeted using the Borg rating scale for dyspnoea [23]. Exercise training within the hospital consisted of treadmill walking (15 minutes), cycle ergometry (15 minutes), and stair climbing (15 minutes). The home exercise programme consisted of a 45 minute period of walking (with the intensity targeted using the Borg rating scale) recorded in a diary card that was reviewed weekly in order to monitor compliance. No formal maintenance training sessions were offered at the end of the 8 week programme and patients only attended the hospital during this time as part of their routine clinical management. All patients were advised, however, on the importance of continuing with the exercises at home in order to maintain the benefits obtained at the end of the programme.

All groups received an 8 week programme of educational sessions which included disease pathology, rationale for training, medication, coping strategies, relaxation, nutritional advice, physiotherapy and smoking cessation (where appropriate).

*Inspiratory Muscle Training (IMT) programme*

Training was performed using a pressure threshold device [26] at an individually programmed intensity. In the PR-IMT group, training started at 30% Pi max and increased by 5% each week until a training intensity of 60% Pi max was achieved. In the PR-SHAM group training was performed at very low load (fixed at 7cmH2O) which has previously been shown to have no effect on the inspiratory muscles in patients with COPD [27, 28].

IMT was performed using an identical technique for both groups. Patients were instructed to insert the mouthpiece and exhale gently as far as possible to residual volume. Following this, they were instructed to take a rapid breath inwards to total lung capacity. Patients were advised that inspiration should last for approximately 2 seconds and expiration for 6 seconds such that the breathing frequency was
approximately 8 breaths per minute. This breathing pattern has previously been shown to improve inspiratory muscle function during IMT in patients with COPD [28].

IMT was performed for 15 minutes, twice daily, at home for 8 weeks. Patients were instructed in the use of the device and maintained a training diary. Training progression was monitored by weekly re-evaluation of Pi max in both training groups and training intensity was adjusted by altering the spring tension within the device. This was performed weekly by the investigator using a pressure transducer to record the inspiratory pressure developed during inspiratory manoeuvres. Patients in the CTRL group did not undergo inspiratory muscle training.

**Statistical Analysis**

Baseline characteristics are reported as mean (SD) with changes from baseline given as mean and the 95% confidence interval. Comparisons of the changes between groups were performed using a one-way ANOVA with significant differences being further investigated using unpaired t-tests with adjustment for multiple comparisons (Bonferroni). Baseline and post training data were compared within groups using a paired t-test.

The study was powered to detect a difference of 20cmH₂O in Pi max (SD 15cmH₂O) between the groups with 80% power and a significance level of 0.05. This indicated 10 patients in each group would be required. A difference in walking distance of 50m (using the ISWT) between the groups (assuming a SD of 40m) would require 11 patients per treatment group.
RESULTS

There were no significant differences between the groups at baseline (Table 1) and no changes in lung function throughout the study. No changes were observed in the control group in any of the parameters measured over the 8 week period.

Table 1  Baseline physiological characteristics of patients who completed the study

<table>
<thead>
<tr>
<th>Parameter</th>
<th>PR-SHAM</th>
<th>PR-IMT</th>
<th>CTRL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male/female</td>
<td>4/7</td>
<td>2/10</td>
<td>0/9</td>
</tr>
<tr>
<td>Smoking status</td>
<td>4 EX/7 NS</td>
<td>2 EX/10 NS</td>
<td>2 EX/7 NS</td>
</tr>
<tr>
<td>Age years</td>
<td>63.1 (3.5)</td>
<td>57.3 (2.4)</td>
<td>62.9 (3.9)</td>
</tr>
<tr>
<td>FEV1 litres</td>
<td>1.44 (0.77)</td>
<td>1.23 (0.74)</td>
<td>1.49 (0.61)</td>
</tr>
<tr>
<td>FEV1 % predicted</td>
<td>64</td>
<td>54</td>
<td>69</td>
</tr>
<tr>
<td>FEV1/VC %</td>
<td>57.0 (0.20)</td>
<td>54.1 (0.20)</td>
<td>66.2 (0.09)</td>
</tr>
<tr>
<td>RV litres</td>
<td>2.14 (0.97)</td>
<td>2.51 (0.95)</td>
<td>1.83 (0.87)</td>
</tr>
<tr>
<td>RV % predicted</td>
<td>111</td>
<td>133</td>
<td>99</td>
</tr>
<tr>
<td>TLC litres</td>
<td>5.04 (1.68)</td>
<td>4.92 (1.10)</td>
<td>4.26 (1.37)</td>
</tr>
<tr>
<td>TLC % predicted</td>
<td>97</td>
<td>98</td>
<td>88</td>
</tr>
<tr>
<td>Tlco mmol/min/kPa</td>
<td>6.32 (2.07)</td>
<td>5.88 (1.61)</td>
<td>5.92 (2.13)</td>
</tr>
<tr>
<td>Tlco % predicted</td>
<td>79</td>
<td>76</td>
<td>76</td>
</tr>
<tr>
<td>Kco mmol/min/kPa/L</td>
<td>1.65 (0.44)</td>
<td>1.63 (0.29)</td>
<td>1.66 (0.35)</td>
</tr>
<tr>
<td>Kco % predicted</td>
<td>86</td>
<td>82</td>
<td>82</td>
</tr>
<tr>
<td>Pi max cm H2O</td>
<td>66.4 (22.0)</td>
<td>78.0 (17.7)</td>
<td>77.2 (24.7)</td>
</tr>
<tr>
<td>Pi max % predicted</td>
<td>87</td>
<td>98</td>
<td>103</td>
</tr>
<tr>
<td>Pe max cm H2O</td>
<td>97.3 (37.5)</td>
<td>75.8 (28.5)</td>
<td>87.4 (22.9)</td>
</tr>
<tr>
<td>Pe max % predicted</td>
<td>66</td>
<td>53</td>
<td>63</td>
</tr>
<tr>
<td>Peak VO2 ml/min/kg</td>
<td>15.6 (6.2)</td>
<td>19.8 (8.3)</td>
<td>19.0 (5.0)</td>
</tr>
<tr>
<td>Peak VO2 % predicted</td>
<td>77</td>
<td>88</td>
<td>92</td>
</tr>
</tbody>
</table>

Baseline physiological characteristics of the 32 patients who were randomised at baseline. All data are expressed as mean (SD). EX = ex smoker; NS = never smoked.

At baseline all 3 patient groups demonstrated a reduction in Pe max (Table 1) compared to the predicted value, which remained unchanged throughout the period of study (data not shown). The groups displayed a wide range of measurements for Pi max (range 36-119 cm H2O) with a significant degree of impairment being observed in some patients.

No changes in respiratory muscle function were observed in the CTRL group over the 8 week period (77.2 (24.7) cm H2O and 75.8 (8.5) cm H2O at baseline and at the end of the 8 weeks respectively). Pi max increased from 78.0 (17.7) cmH2O at baseline to 100.5 (25.7) cmH2O at the end of training (p=0.003) in the PR-IMT group (Figure 1a) with a similar increase in the PR-SHAM group (Figure 1b). There was no significant difference between the magnitude of the increase in Pi max between the 2 training groups (p=0.220; Table 2).
Similarly, there was no difference between the groups in the magnitude of the change between the end of training and 3 months post training (-9.7 cm H₂O, 95% confidence interval -17.5 to -1.8 cm H₂O in the PR-IMT group and (-1.9 cm H₂O, 95% confidence interval -12.7 to 9.0 cm H₂O in the PR-SHAM group; p=0.186). We were unable to obtain data from 2 patients in each group at this 3 month follow up. Individual data obtained at this time is shown in Figures 1a and 1b for the PR-IMT and PR-SHAM groups respectively.

Table 2 Comparison of changes between the groups during the study

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Change between baseline and end of training</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PR-SHAM</td>
</tr>
<tr>
<td>Pi max cmH₂O</td>
<td>12.0* (1.1 – 22.9)</td>
</tr>
<tr>
<td>VO₂ peak ml/min/kg</td>
<td>1.96 (-1.8 – 5.7)</td>
</tr>
<tr>
<td>ISWT metres</td>
<td>96.7** (59.6 – 133.7)</td>
</tr>
<tr>
<td>Endurance exercise metres</td>
<td>392.8** (251.7 – 534.0)</td>
</tr>
</tbody>
</table>

P-value represents the difference between the 3 groups (using ANOVA) at the time point shown. The numbers in parentheses represent the 95% confidence interval. *p<0.05 and **p<0.01 comparing CTRL to PR-SHAM; ##p<0.01 comparing CTRL to PR-IMT.

No changes in peak oxygen uptake were observed in any of the three groups at the end of the 8 week period (Table 2). In contrast, there were significant improvements in endurance exercise capacity in both the PR-IMT group (mean increase 607.3 metres, 95% confidence interval 436.0 to 778.7 metres) and the PR-SHAM group (mean increase 392.8 metres, 95% confidence interval 251.7 to 534.0), the magnitude of which was similar between the groups. Individual patient data is shown in Figures 2a and 2b respectively.

Similarly, the percentage increases in walking distance were also similar between the two training groups (PR-IMT mean % change 205.7, 95% confidence interval 34.7 – 426.1; PR-SHAM mean % change 174.9, 95% confidence interval 31.6 – 310.6). No changes in endurance exercise capacity were observed in the CTRL group (Table 2).

Three months after the training programme had ended the improvement in endurance exercise capacity was maintained in the PR-IMT group (Figure 2a) but not in the PR-SHAM (Figure 2b) group (1394.7 (347.7) metres and 398.1 (114.2) metres in PR-IMT and PR-SHAM groups respectively; p<0.01). Furthermore, the change between the end of training and 3 months post training was significantly different between the groups (-60.8 metres, 95% confidence interval -203.4 to 81.7 metres and -382.9 metres, 95% confidence interval -602.1 to 163.7 metres for the PR-IMT and PR-SHAM groups respectively; p=0.01).

ISWT distance improved from 425.0±182.9 metres to 579.1±134.9 metres (p=0.001) in the PR-IMT group (Figure 3a) and from 328.2±231.9 metres to 387.8±115.8
metres (p=0.0003) in the PR-SHAM group (Figure 3b). There was no difference in the magnitude of the improvement between the two training groups (mean change 124.5 metres, 95% confidence interval 63.2 to 185.9 metres in the PR-IMT group; mean change 96.7 metres, 95% confidence interval 59.6 to 133.7 metres in the PR-SHAM group). There were no significant changes in the ISWT in the CTRL group (Table 2).

The improvement in ISWT was maintained 3 months post training in the PR-IMT group (579.1±134.9 metres at the end of training and 568.8±114.4 metres 3 months post training; p=0.121) but not in the PR-SHAM group (Figure 3b). A comparison of the magnitude of the change between the end of training and 3 months post training (-31.1 metres, 95% confidence interval -71.7 to 9.5 metres and -96.3 metres, 95% confidence interval -169.4 to 23.1 metres for the PR-IMT and PR-SHAM groups respectively; p=0.07) just failed to reach statistical significance which may relate to the fact that a further two patients withdrew from each group at this time and the sample size was thus reduced.

There were no significant differences in health status at baseline between any of the groups. Patients in the PR-IMT group demonstrated a significant improvement in the total score for the SGRQ (mean change -7.7, 95% confidence interval -16.6 to 1.1) when compared to the CTRL group (p=0.05) that was greater than the minimum clinically important difference (4 points). Three months after the end of the programme the SGRQ score remained significantly improved compared to baseline (mean difference -10.0, 95% confidence interval -21.3 to 1.3). There were no significant changes in health status in the PR-SHAM group (mean change 2.3, 95% confidence interval -2.9 to 7.4; p=0.422 compared to CTRL) at the end of the training programme despite improvements in exercise capacity.

At the end of the training programme there were no changes in 24 hour sputum volume in the PR-IMT group (14.8±12.1 and 10.6±9.5ml at baseline and at the end of training respectively; p=0.424), the PR-SHAM group (12.4±5.7 and 9.8±6.1ml respectively; p=0.144) or the CTRL group (17.8±10.1 and 16.9±15.1ml respectively; p=0.386).
DISCUSSION

This is the first study to investigate the effects of exercise training in patients with Bronchiectasis and has shown that the improvements in exercise capacity are similar to those obtained after pulmonary rehabilitation in patients with COPD. Pulmonary rehabilitation, incorporating high intensity exercise training, was effective in improving both ISWT distance and endurance exercise capacity in patients with Bronchiectasis. Targeted IMT resulted in significant improvements in respiratory muscle strength in the PR-IMT group but did not provide additional immediate benefit above the effects of exercise training.

The failure of IMT to enhance the magnitude of the improvements in exercise performance induced after high intensity exercise training is similar to the findings of both Berry et al [29] and Larson et al [30] in studies of patients with COPD and may have occurred for several reasons. Firstly, the high intensity of the exercise training performed may have induced the maximum attainable benefits in exercise capacity in both PR-IMT and PR-SHAM groups such that there was no further benefit with the addition of IMT. Indeed, the intensity of the exercise training was sufficient to induce a significant improvement in $P_{i\text{ max}}$ even in the PR-SHAM group after training despite there being no targeted IMT in this group.

Secondly, patients demonstrated either normal or only mildly reduced inspiratory muscle strength at baseline which suggests that functional weakness of the inspiratory muscles was not a major cause of dyspnoea. Indeed, in the study by Larson et al [30] in which no additional benefit of IMT was found in conjunction with exercise training, the baseline inspiratory muscle strength of the patients studied was also within normal limits. Finally, the low number of subjects studied may have been inadequate to demonstrate a small but significant difference between the groups. Indeed, to detect a statistically significant difference in the magnitude of the improvements in ISWT distance between PR-IMT and PR-SHAM groups would have required 59 patients in each patient group, based on the observed average changes of 124.5 metres and 96.7 metres for the PR-IMT and PR-SHAM groups respectively.

In the PR-IMT group the improvements in both exercise capacity and health status observed at the end of the training programme were maintained 3 months after the cessation of training as shown previously in patients with COPD where improvements have been maintained for up to 11 months [31, 32, 33]. In contrast, the increase in exercise performance in the PR-SHAM group was not maintained, which could suggest an additive effect of IMT in the PR-IMT group. While this may relate to a decrease in the perception of dyspnoea during exercise after specific IMT [13], this was not investigated during the present study.

We found no statistically significant changes in 24 hour sputum volume in any of the training groups suggesting that neither exercise training nor IMT affected sputum clearance in this group of patients. While there have been no previous studies investigating the role of exercise training as an aid to sputum clearance in patients with Bronchiectasis, these results are similar to those obtained by Salh et al [34] in adult patients with Cystic Fibrosis.
In summary, pulmonary rehabilitation resulted in improvements in health status and exercise capacity in patients with Bronchiectasis that were similar in magnitude to those in patients with COPD. IMT conferred no immediate additional benefits in terms of exercise performance but may influence the longevity of the observed training effects. These results highlight the potential role of pulmonary rehabilitation in patients with Bronchiectasis although further studies are necessary to identify the most eligible patients and to optimise the training programmes to maximise the training response and maintenance of the benefits.

There are no competing interests to be declared.
Figure 1a  Individual changes in Pi max during training in the PR-IMT group

Individual values for Pi max during training is shown. The lines join data for individual patients

Figure 1b  Individual changes in Pi max during training in the PR-SHAM group

Individual values for Pi max during training is shown. The lines join data for individual patients

Figure 2a  Individual changes in endurance capacity during training in the PR-IMT group

Individual data and changes in endurance capacity are shown before and after 8 weeks training.

Figure 2b  Individual changes in endurance capacity during training in the PR-SHAM group

Individual data and changes in endurance capacity are shown before and after 8 weeks training.

Figure 3a  Individual changes in ISWT during training in the PR-IMT group

Individual changes in ISWT at the start and end of the training programme.

Figure 3b  Individual changes in ISWT during training in the PR-SHAM group

Individual changes in ISWT at the start and end of the training programme.
REFERENCES


Figure 1a  Individual changes in Pi max during training in the PR-IMT group

Figure 1b  Individual changes in Pi max during training in the PR-SHAM group
Figure 2a Individual changes in endurance capacity during training in the PR-IMT group

Figure 2b Individual changes in endurance capacity during training in the PR-SHAM group
Figure 3a  Individual changes in ISWT during training in the PR-IMT group

Figure 3b  Individual changes in ISWT during training in the PR-SHAM group
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