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Effect of addition of exercise to chest physiotherapy on sputum expectoration and lung function in adults with cystic fibrosis

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Promotion of sputum expectoration by chest physiotherapy is an essential part of cystic fibrosis management. The role of exercise in improving sputum expectoration and lung function in these patients is more contentious. We therefore investigated the effect of adding an exercise programme to conventional chest physiotherapy in eight adult subjects (four male) with cystic fibrosis. Subjects were treated on two non-consecutive days of the second week of a course of in-patient antibiotic therapy in a cross-over fashion. On the exercise and physiotherapy day, subjects exercised 60 min before physiotherapy. On the physiotherapy alone day, subjects rested for 60 min instead of exercising. Physiotherapy was administered on both study days (postural drainage, percussion, deep breathing, vibrations, forced expiratory technique and coughing).

Lung function tests were performed at baseline, after exercise or rest and again immediately and 30 min after physiotherapy. Sputum weights were measured in the 60 min of exercise or rest (period A) and for the 60 min physiotherapy period and 30 min after physiotherapy (period B). Mean total sputum expectoration (period A and B) was 14 g on physiotherapy alone and 21·5 g (4·8) on exercise and physiotherapy (mean difference 7·5 g, 95% CI 1·4–13·6 g, $P=0·02$). Mean sputum weights during period A (i.e. rest *vs.* exercise) on physiotherapy alone and exercise and physiotherapy were 2·6 and 7 g respectively (mean difference 4·4 g, 95% CI −0·07–8·8 g, $P=0·053$). Values for mean sputum weights during physiotherapy (period B) on physiotherapy alone and physiotherapy plus exercise were 11·4 and 14·5 g respectively (mean difference 3·1 g 95% CI 1·2–5·1 g $P=0·007$).

No significant difference in FEV_1, FVC, FEF_{25-75} and peak expiratory flow rate was shown between physiotherapy alone and physiotherapy and exercise. In conclusion, exercise itself leads to more sputum expectoration than occurs at rest and further increases sputum clearance afforded by physiotherapy. However, neither physiotherapy nor exercise have significant effects on lung function acutely.

Introduction

The importance of clearance of sputum from the lungs in patients with cystic fibrosis and other forms of bronchiectasis is widely appreciated (1–4). The value of physiotherapy in encouraging sputum expectoration has been well established, some (2,3), holding the view that all of the recognized manoeuvres of postural drainage, vibrations, deep breathing, forced expiratory technique and coughing are important, whilst others doubt the value of any of these techniques if coughing alone yields little sputum (5). The addition of a programme of exercise to physiotherapy, as a means of further increasing sputum expectoration and therefore improving lung function has not been extensively studied. In one preliminary study no significant increases in either sputum production or lung function were shown (6), although not all the recognized modalities of physiotherapy were employed (2) and therefore optimal treatment might not have been given. We therefore compared the effect of a combination of physiotherapy and exercise with physiotherapy alone on sputum expectoration and lung function in a group of patients with cystic fibrosis We specifically chose an exercise programme which was practically orientated and used several forms of exercise and modalities of physiotherapy to try to maximize any effect.

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Methods

SUBJECTS

Eight adult subjects (four male) aged between 18 and 27 years with cystic fibrosis were studied. Their mean (SEM) percentage of predicated FEV_1 was 63·6% (6·6). Subjects had a median of three hospital

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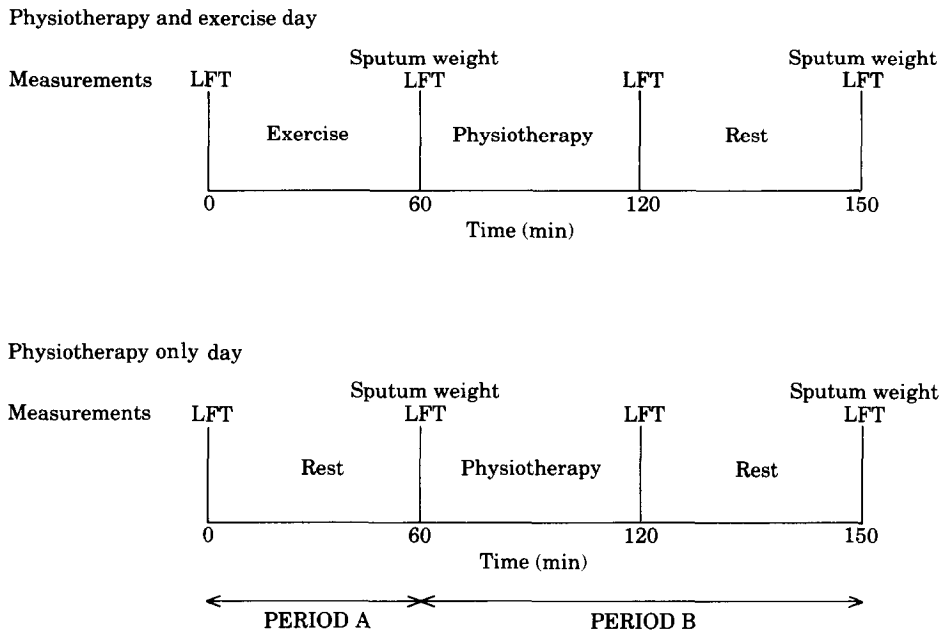

Fig. 1 Study protocol.

admissions in the last year (range 0–5). All had airways chronically colonized with *Pseudomonas aeruginosa*. All patients were on intravenous antibiotics (four ceftazidime, two azlocillin + gentamicin, two aztreonam + gentamicin/tobramicin). Two were on nebulized β_2-agonists and these were administered 1 h before the study period on both study days. Patients gave written informed consent and the study was approved by the City Hospital Ethics Committee.

PROTOCOL

Subjects were studied on two non-consecutive days during the second week of a 2-week course of in-patient treatment with intravenous antibiotics. Subjects were randomized to receive either physiotherapy or physiotherapy with a preceding exercise programme in an open randomized cross-over manner. Subjects were studied at the same time of day on both study days. Treatment was performed by the same physiotherapist on each occasion. On the exercise day patients had baseline forced expiratory volume in 1 s (FEV_1), forced vital capacity (FVC), FEF_{25-75}, and peak expiratory flow rate (PEFR) recorded followed by an exercise programme lasting 40 min. Weight of wet sputum collected over this period and for a further 20 min was recorded (period A). Physiotherapy was then administered and lung function tests repeated after a further 60 min. Sputum was collected over this period and for a further 30 min afterwards (period B). Finally, lung function tests were repeated. On the physiotherapy only day, patients rested for the first 60 min, but they were not confined to bed nor their activity restricted. Physiotherapy was then performed in an identical manner to the exercise and physiotherapy day. Sputum was collected during this period and lung function tests performed in an identical manner to the exercise and physiotherapy day (see Fig. 1). If patients were taking β-agonists (two patients) these were administered in an identical manner on both study days 60 min prior to commencing the protocol.

CHEST PHYSIOTHERAPY

The physiotherapy regime utilized included postural drainage, percussion, deep breathing, vibrations, forced expiratory technique (huffing) and coughing. With the patient in the necessary postural drainage position, percussion was performed until the patient could complete five comfortable, deep breaths. Following this patients were asked to take five relaxed breaths, then five deep breaths with vibrations on expiration, two huffs and cough. This cycle of treatment was performed until the amount of sputum expectorated was reduced to nothing. This ranged from 25 to 40 min for individual patients. The physiotherapy regime commenced at the same time on both the exercise and physiotherapy and physiotherapy alone days to eliminate any time dependent variants.

Table 1 Lung function on physiotherapy and exercise and physiotherapy only days

	Time (min)	Mean (SEM) FEV_1 (l)	FVC (l)	PEFR (l min^{-1})	FEF_{25-75} (l)
Physiotherapy only	0	1·58 (0·13)	2·78 (0·40)	345 (35)	0·96 (0·14)
	60	1·56 (0·15)	2·83 (0·48)	349 (34)	0·99 (0·16)
	120	1·58 (0·15)	2·69 (0·39)	350 (32)	0·96 (0·15)
	150	1·59 (0·14)	2·85 (0·41)	364 (35)	0·90 (0·14)
Physiotherapy and exercise	0	1·53 (0·17)	2·56 (0·37)	367 (27)	0·97 (0·18)
	60	1·52 (0·12)	2·58 (0·35)	363 (28)	1·01 (0·18)
	120	1·56 (0·17)	2·58 (0·35)	369 (31)	1·02 (0·19)
	150	1·54 (0·16)	2·63 (0·42)	378 (31)	0·92 (0·16)

Table 2 Sputum production on physiotherapy alone and exercise and physiotherapy days

	Mean (SEM) wet sputum weight (g)		
	Period A	Period B	Period A & B
Physiotherapy alone	2·6 (1·4)	11·4 (3·9)	14·0 (5·2)
Exercise and physiotherapy	7·0 (1·9)	14·5 (3·6)	21·5 (4·8)

EXERCISE REGIME

The precise exercise regime consisted of:

1. Brisk walk to the gym from the ward.
2. Warm-up stretch exercises.
3. Cycling for 1 min.
4. Steps up for 1 min at a brisk pace.
5. Star jumps for 1 min.
6. Trampete jumping for 1 min.
7. Rowing for 1 min.
8. Jogging on the spot for 1 min.

One minute rest was allowed between exercises. Patients could terminate or reduce the intensity of the session at any point; in this instance all readings were still recorded at the same time points.

LUNG FUNCTION

FEV_1, FVC and FEF_{25-75} were measured as the highest of three manoeuvres on a Vitalograph alpha® spirometer. PEFR was measured as the highest of three readings on a Wright® peak flow meter.

STATISTICAL ANALYSIS

Baseline values and the values at the end of period A and B for sputum weight, FEV_1, FVC FEF_{25-75} and PEFR were compared on the two study days using Student's two-tailed paired *t*-test. A *P* value of $<0·05$ was considered to be statistically significant.

Results

None of the baseline spirometric variables differed significantly on the two study days (Table 1). Table 2 shows the mean (SE) wet sputum weights recorded on exercise and physiotherapy, and physiotherapy only days. Mean total sputum expectoration (Periods A & B) was 14 g on physiotherapy alone and 21·5 g on exercise and physiotherapy (mean difference 7·5 g, 95% CI 1·4–13·6 g, $P=0·023$).

Mean sputum production during period A (i.e. during rest *vs.* exercise) was 2·6 g on physiotherapy alone and 7 g on exercise [mean difference 4·4 g, 95% CI ($-0·07$–8·8), $P=0·053$].

Mean sputum production during period B (i.e. during and for 30 min after physiotherapy) was 11·4 g on physiotherapy alone and 14·5 g on exercise and physiotherapy (mean difference 3·1 g, 95% CI 1·2–5·1 g, $P=0·007$).

There was no significant difference in any spirometric variable between the two study days. (Table 1).

All patients when asked stated a preference for the day on which exercise and physiotherapy were combined.

Discussion

The aim of our study was to determine if addition of an exercise program to physiotherapy increased

sputum production in cystic fibrosis. The study had an open randomized cross-over design. Although it is possible that its open nature introduced some bias, it is difficult to eliminate this problem in studies of physical treatment. Physiotherapy was performed by the same physiotherapist each time to ensure that it was standardized. Tests were performed on two non-consecutive days in case there was any carry over effect of treatment. The exercise programme consisted of a series of exercises performed at the maximum workload that the patients could comfortably tolerate and were therefore set subjectively by the patients rather than at any objective workload. It was thought that exercise performed in this manner would be more representative of the clinical situation and therefore more applicable than performing exercise at a fixed $\dot{V}O_2$ max. We found in our short term study that exercise by itself increased sputum production (i.e. during period A) compared to rest although the almost three-fold increase seen was just outside statistical significance. Other longer term studies in cystic fibrosis have also shown a beneficial effect of exercise on sputum production in both adults and children (7,8). Sahl and colleagues (7) in twelve patients showed a 50% increase in sputum production after 2 months of an exercise training programme. Exercise alone had no effect on pulmonary function in our study. However, several studies have shown that regular exercise can improve lung function and performance in cystic fibrosis when given over a longer time span (8–12), possibly reflecting an increase in fitness. These findings taken in conjunction with ours suggest that exercise can have both short term and long term benefits in cystic fibrosis.

We also found that prior exercise significantly increased sputum expectoration during physiotherapy (period B) when the combination of exercise and physiotherapy was significantly better than physiotherapy alone. Two previous studies have directly compared physiotherapy with exercise in cystic fibrosis (7,13) but only one has looked at combining these techniques (6). In the two direct comparison studies, Sahl *et al.* (7) showed that exercise increased sputum production, in adults with cystic fibrosis but by not as much as physiotherapy, whereas a study by Zach *et al.* (13) suggested that exercise could be substituted for physiotherapy without deterioration in most patients in a study of children albeit with a higher intensity of exercise. We did not compare exercise as an alternative but rather as an adjunct to physiotherapy. We found that a combination of exercise and physiotherapy significantly increased sputum compared to physiotherapy alone. This contrasts with the only other study to compare the addition of these treatments with physiotherapy alone, a study by Bilton *et al.* (6) who found no significant difference. The difference between our findings and those of Bilton and colleagues may reflect differences in study design. In our study the duration of physiotherapy was identical (25–40 min in individual patients) irrespective of whether or not exercise was added. It could be argued that we would have produced comparable benefit by performing two sessions of physiotherapy rather than adding exercise to physiotherapy. Whilst this is a possibility, it is unlikely that the patients would have easily tolerated a second physiotherapy session. In contrast all patients found that a combination of exercise and physiotherapy was subjectively better than physiotherapy alone and was well tolerated. As the reason for terminating physiotherapy was that no further sputum could be expectorated it would seem unlikely that further physiotherapy sessions would have been useful.

The mechanism by which exercise increases sputum production during physiotherapy is not known. Sutton has suggested that exercise may produce minor bronchodilatation due to release of endogenous catecholamines (4). If this were the only mechanism, however, then nebulized β_2-agonists might have a greater effect of sputum production than exercise. We did not find any bronchodilatation after exercise in our study. It is more likely that exercise serves to dislodge sputum from peripheral sites in a similar fashion to physiotherapy, and that partially loosened sputum is then easier to move into larger airways for expectoration.

In addition to looking at the additive effects of exercise and physiotherapy on sputum production we looked at the effect on lung function. Conventional chest physiotherapy regimes have been shown to maintain lung function in paediatric cystic fibrosis patients compared with patients given no physiotherapy, in whom lung function (FVC, FEV_1, FEF_{25-75}) were measured over a 3-week period (2). As it is not clear which components of the regimen are the most important (4,14), we used all of the recognized manoeuvres to try and ensure that a fully effective regimen was employed in our study. We were unable to determine any difference in lung function between physiotherapy alone and exercise and physiotherapy days. However our tests were performed acutely, and therefore do not give information about the effect of adding exercise to physiotherapy on lung function on lung function in the longer term. It is possible that combining exercise and physiotherapy over a prolonged period might lead to improvement in lung function, although no such improvement was seen in the study by Sahl *et al.* (7).

In conclusion we have shown that exercise is a useful adjunct to physiotherapy in aiding sputum

production in patients with cystic fibrosis. The practical problems of performing exercise regimes during exacerbations may preclude their use in patients who are feeling particularly unwell but are likely to be useful during the recovery phase. Although compliance might be a problem due to the increased length of treatment, the subjective preference shown by the patients for the day which included exercise might act in an opposite manner to increase compliance. An exercise regime such as ours may be acceptable to patients who have a general interest in physical fitness.

References

1. Pryor JA, Webber BA, Hodson ME, Batten JC. Evaluation of the forced expiration technique as an adjunct to postural drainage in treatment of cystic fibrosis. *BMJ* 1979; **ii:** 417–418.
2. Desmond KJ, Schwenk W, Thomas E, Beaudry P, Coates AL. Immediate and long term effects of chest physiotherapy in patients with cystic fibrosis. *J Pediatr* 1983; **103:** 538–542.
3. Reisfnan J, Rivington-Law B, Corey M. *et al.* Role of conventional physiotherapy in cystic fibrosis. *J Pediatr* 1988; **113:** 632–636.
4. Sutton PP. Chest physiotherapy: Time for reappraisal. *Br J Dis Chest* 1988; **82:** 127–134.
5. Geddes DM. Cystic fibrosis: Future trends in care. *Thorax* 1988; **43:** 869–871.
6. Bilton D, Dodd M, Webb AK. Evaluation of exercise as an adjunct to physiotherapy in the treatment of cystic fibrosis. *Thorax* 1989; **44:** 859P.
7. Sahl DL, Bilton D, Dodd M, Webb AK. Effect of exercise and physiotherapy in aiding sputum expectoration in adults with cystic fibrosis. *Thorax* 1989; **44:** 1006–1008.
8. Zach MS, Purrer B, Oberwaldner B. Effect of swimming on forced expiration and sputum clearance in cystic fibrosis. *Lancet* 1981; **ii:** 1201–1203.
9. Orenstein DM, Franklin BA, Doershuk *et al.* Exercise conditioning and cardiopulmonary fitness in cystic fibrosis. *Chest* 1981; **80:** 392–398.
10. Cropp GJ, Pullano TP, Cerny FJ, Nathanson IT. Exercise tolerance and cardiorespiratory adjustments at peak work capacity in cystic fibrosis. Am Rev Respir Dis 1982; **126:** 211–220.
11. Anderson B, Jonson B, Kornfalt R *et al.* Long-term effects of physical exercise on working capacity and pulmonary function in cystic fibrosis. Acta Paediatr Scand 1987; **76:** 70–75.
12. O'Neill P, Dodd M, Phillips B, Poole J, Webb AK. Regular exercise and reduction of breathlessness in patients with cystic fibrosis. *Br J Dis Chest* 1987; **81:** 62–69.
13. Zach MS, Oberwaldner B, Hausler F. Cystic fibrosis: physical exercise versus chest physiotherapy. *Arch Dis Child* 1982; **57:** 587–589.
14. Rossman M, Walders R, Sampson D, Newhouse MT. Effect of chest physiotherapy on the removal of mucus in patients with cystic fibrosis. *Am Rev Respir Dis* 1982; **126:** 131–135.