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Effects of Chest Physical Therapy on Lung Function in Children Recovering From Acute Severe Asthma

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Summary. The effects of chest physical therapy in acute severe asthma in children have been studied in 38 children aged 6 to 13 years in a randomized placebo controlled trial. The study began between 6 and 24 hours after admission to hospital; 19 children received chest physical therapy (PT) and 19 children received placebo visits. Each child had 4 treatments over 2 days which were preceded by nebulized salbutamol. Lung volumes and flow rates were measured in a body plethysmograph before salbutamol and before and after either PT or placebo on the first and fourth treatments. Throughout the study standard asthma drug therapy was given. In both groups characteristics such as sex, race, age, height, weight, severity, and baseline lung function were similar. Taking into account the baseline, lung function at the end of the study was similar in both groups. Three 12 year old children in the PT group showed improvements in flows above those seen in any children in the placebo group. We conclude that chest PT, when combined with asthma drug therapy, does not improve lung function in most children in this age group with acute severe asthma. **Pediatr Pulmonol 1990; 9:146–151.**

Key words: **Respiratory therapy, breathing exercises, inducement of expectoration; lung volumes, expiratory flow rates; clinical score, length of hospitalization; randomized, placebo controlled study.**

INTRODUCTION

Physiotherapy is variably used in the convalescent phase of acute severe asthma attacks. The role of a physiotherapist includes education of the patients, instruction about inhaled drug therapies, and administering chest physical therapy (PT). Chest PT is aimed at improving the clearance of mucus which is known to accumulate in patients with asthma of all degrees of severity.[1,2] Long-term breathing exercises in asthma may also improve the efficiency of breathing and even increase the vital capacity.[3]

There have been very few studies of the effects of chest PT in acute severe asthma in children[4] and none placebo controlled or extended beyond several hours.[5] Studies in children with cystic fibrosis indicate that chest PT may offer most benefit at initiation of treatment.[6] Although no definitive study of its value has been conducted in acute asthma, PT is sometimes used in this setting, after the most acute bronchospasm has subsided. It has been shown that different techniques for aiding mucus clearance may produce similar degrees of improvement in lung function,[8] although these therapies have not been compared with placebo.

Acute severe asthma is usually treated with β_2-sympathomimetics and theophylline which may have beneficial effects on tracheo-bronchial mucociliary clearance directly[9,10] or by reducing expiratory flow limitation. The use of potent anti-asthma drugs with such effects is likely to overwhelm benefits, if any, of PT. The place of chest PT in the routine management of acute severe asthma needs to be evaluated.

This study aimed to examine the effects of PT on lung mechanics and overall progress, in children recovering from uncomplicated acute severe asthma attacks, while they were in hospital receiving anti-asthma drug therapy.

MATERIALS AND METHODS

Subjects

Thirty eight children aged 6 to 13 years with acute severe asthma admitted to Auckland Hospital were re-

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cruited for the study between February and August 1985. Acute severe asthma was defined as "acute asthma poorly responsive to inhaled bronchodilator on admission to hospital." Approval of the project was granted by the Auckland Hospital Ethical Committee and informed consent was obtained from the parents. If the parents or doctor wanted to withdraw the child for any reason permission was granted. Patients who were critically ill or who had complications on chest radiograph such as lobar atelectasis or pneumonia were eliminated from the trial; only one child (with extrapulmonary air) was thus excluded. A maximum of 2 patients were entered on each study day (Monday to Wednesday each week) and the remainder were eliminated by random sampling.

Study Design

Nineteen patients received PT and 19 received placebo treatment. A randomized placebo controlled study was used. Subjects were assigned using a table of random numbers to either a placebo treatment group or a PT group. Patients on or off oral or parenteral glucocorticosteroids were independently randomized. Treatments were started in the study between 6 and 24 hours after admission to hospital. Each child then received four treatments over a 2 day period (2 each day).

The first treatment began in the morning and subsequent ones were separated by approximately 4 hours. Each treatment period lasted about 1 hour. Before every treatment patients received inhaled salbutamol (2.5 mg) via a nebulizer over 10 minutes, followed by a rest period of 20 minutes. This was followed by either a placebo treatment or PT lasting 20 to 30 minutes. Complete lung function measurements were performed before and 20 minutes after Salbutamol inhalations, and immediately following the first and fourth placebo or PT treatments.

The placebo treatment consisted of a visit for 20 minutes by a volunteer from the "Children in Hospital Liaison Group." These volunteers are trained in giving emotional support to children in hospital and their main duties during this study were to provide "tender loving care." They were instructed to provide no form of chest physical therapy and to ignore coughing. Each child had only one volunteer for all four treatments. Sputum production was not assessed in this group.

During PT sessions appropriate techniques were selected by the physiotherapist according to the patient's presentation; each child had one experienced pediatric physiotherapist for all four treatments. Techniques were used to help clear secretions, achieve relaxation, minimize ineffective breathing movements, and optimize drug therapy (Table 1). Education and psychological support were also provided as appropriate. Techniques often changed from the first to the fourth treatment, according to patient's progress. Diaphragmatic breathing was used invariably to gain better lung expansion and relaxation, while vibrations were used to help remove secretions. In the less severe and subacute patients more emphasis was placed and time spent on forced expiration technique for removal of secretions. Percussion was used infrequently, most often with less severe and subacute patients. When sputum was produced during a treatment it was collected and weighed.

TABLE 1—Chest Physical Therapies Used in Study (in %-per-group)

	First treatment		Fourth treatment	
	Total group	Severe[a] group	Total group	Severe[a] group
Relaxation				
Any method	95	100	84	88
Positioning	68	63	32	25
Lateral costal breathing	89	88	74	75
Diaphragmatic breathing	95	100	84	88
Relaxation of shoulder girdle	68	75	53	63
Clearance of secretions				
Any method	79	88	74	88
Postural drainage	79	88	74	63
Coughing	26	88	74	88
Forced expiration technique	79	38	74	63
Vibration	32	75	58	88
Wing flapping	5	0	10	0
Percussion	26	13	74	88
Thoracic mobility exercises	5	100	10	88
Postural correction exercises	10	13	42	50

[a]Severe: patients with clinical score ≥7.

Measurements

Assessments on admission included recording the age at onset of asthma, the history of asthma in the last 12 months, recent and current drug regimens, acid base status, measuring peak expiratory flow, chest radiography, ECG, noting presence of sputum in the 24 hours before admission, and establishing a clinical score of the patient. The clinical score, like one used in adults,[11] was based on pulse rate, respiratory rate, pulsus paradoxus, accessory muscle use, and chest retractions (Table 2). A score of 15 was the worst possible obtainable and a score of 0 indicated normal parameters. All parameters were recorded by residents, before the child entered the study. Best peak flow rate on discharge, days in hospital, and further admissions over the subsequent year were also measured.

All lung volumes and maximum expiratory flow-volume curves were measured by one technician in a volume displacement body plethysmograph, using techniques described for this laboratory.[12] The technician was blinded to the treatment received by subjects. At least 3 slow and fast vital capacities were done and the biggest of three satisfactory attempts of each was taken for analysis. Vital capacity (VC), forced vital capacity

TABLE 2—Clinical Scoring System

		SCORE
Pulse rate (beats/min)	<100	0
	100–120	1
	121–140	2
	>140	3
Resp rate (breaths/min)	<20	0
	21–30	1
	31–40	2
	41–50	3
	>50	4
Pulsus paradoxus (mm Hg)	<5	0
	6–10	1
	11–15	2
	16–20	3
	>20	4
Retractions	Absent	0
	Mild-moderate	1
	Moderate-severe	2
Accessory muscle use	Absent	0
	Mild-moderate	1
	Moderate-severe	2
Maximum score (worst)		15

(FVC), expiratory reserve volume (ERV), and functional residual capacity (FRC) were measured directly. Residual volume (RV) and total lung capacity (TLC) were derived from direct measurements. The flows measured included peak expiratory flow rate (PEFR), maximum mid expiratory flow (FEF_{25-75}), and forced expired volume in 1 second (FEV_1). Lung volumes and flow rates were expressed as percent predicted compared to reference standards for our laboratory.[12]

The best of 3 flow-volume curves were used in calculating flows at low lung volumes. To eliminate changes in expiratory flow that resulted from changes in lung volume, maximal expiratory flow rates at 25 and 50% of baseline VC ($\dot{V}_{max\ 25VC}$, $\dot{V}_{max\ 50VC}$) and 60% of baseline TLC ($\dot{V}_{max\ 60\ TLC}$) were measured.[6,13]

Statistical Analysis

All data were analyzed using an IBM 4341 computer and appropriate statistical programs (SAS Institute Inc). Characteristics of the individuals were treated by univariate analysis. Baseline lung function (percent predicted) and patient characteristics were compared between groups using unpaired t tests. Analysis of covariance was used to compare final lung function parameters (percent predicted) between the two groups taking into consideration the baseline lung function. To allow for missing information (4 individuals), the analysis looked at individuals with full data for each variable.

RESULTS

Because of readmissions during the study period, 3 children were enrolled twice, 1 in the placebo group, and 2 in the PT. Four subjects completed the initial treatment but not the final treatment: one of each group because of early discharge (1.0 and 1.5 days), and one child of the PT group who withdrew twice because of headache and vomiting.

TABLE 3—Characteristics of Study Subjects

	Placebo	PT
No. of subjects	19	19
No. of subjects completing study	18	16
Sex		
M	9	11
F	10	8
Race		
European	10	9
Maori	4	6
Pacific Island	3	1
Other	2	3
Age (yr)	10.0 ± 2.6[a]	9.5 ± 2.7
Height (cm)	138.8 ± 15.5	138.0 ± 16.5
Weight (kg)	32.6 ± 10.5	33.9 ± 12.7
Age at onset of asthma (yr)	2.1 ± 2.9	2.7 ± 1.7

[a]Mean ± SD.

Characteristics of the subjects were evenly distributed between the two groups with no significant differences in age, height, or weight (Table 3). Admission characteristics were similar between groups (Table 4). The severity of asthma in the last 12 months was also scored and was similar in the two groups (Table 5).

Drug treatments received as inpatients during the study included nebulized salbutamol (2.5–5.0 mg, 4 hourly), theophylline to a target serum concentration of 55–82 μmol/L (usually intravenous aminophylline), and, in 30 patients, oral or parenteral steroid (usually hydrocortisone (5 mg/kg/6 hours). There were 15 patients on steroids in each of the treatment groups. Steady-state theophylline levels were 70.4 ± 10.2 μmol/L ($\bar{X}$ ± SD) in the placebo group and 81.5 ± 21.2 in the PT group.

Chest PT techniques used at the first and fourth treatment of the study group are described in Table 1. Relaxation techniques were used most commonly, followed by induced clearance of secretions. At the first treatment, coughing was used more commonly among more severely ill subjects and forced expiration technique among the less severe ones.

Lung volumes and flow rates for both groups are summarized in Tables 6 and 7. The placebo and PT groups showed no statistical differences in baseline lung function. Taking into consideration the baseline, lung function at the end of the study was not statistically different between groups. Although the PT group showed greater improvement in expiratory flows at low lung volumes, these differences can be accounted for by results in 3 subjects.

TABLE 4—Patient Characteristics on Admission[a]

	Placebo	PT
Duration of attack (days)	3.0 ± 4.1	4.5 ± 7.6
Clinical score	7.3 ± 3.2	7.6 ± 3.8
Peak flow (L/min)	121 ± 83	128 ± 64
pH	7.39 ± 0.07	7.42 ± 0.04
Pa_{CO_2} (kPa)	5.0 ± 1.0	4.8 ± 0.5
Sputum in last 24 hours (n)	8	8
Steroids (n)	15	15

[a]Mean ± SD.

TABLE 5—Severity Score of Asthma in Last 12 Months

3 = Severe	
	>1 admission or >3 urgent visits to medical practitioner
2 = Moderate	
	1 or 2 urgent visits to medical practitioner, or frequent waking from asthma, or frequent school absences
1 = Mild	
	Less than above
Score[a]	
Placebo group	PT group
2.3 ± 0.8	2.4 ± 0.8

[a]Mean ± SD.

Six PT and 7 placebo patients improved during both the first and fourth treatments as measured by $\dot{V}_{max\ 25VC}$ (Fig. 1). Among the 7 placebo patients $\dot{V}_{max\ 25VC}$ improved by an average of 188% above the initial value, whereas the 6 PT patients improved by an average of 403% above the initial value. Three of the 19 PT patients (16%) showed a degree of improvement in $\dot{V}_{max\ 25VC}$ consistently greater than that seen in the placebo group. These 3 patients were 12 year old boys whose asthma had started at 2 or 3 years of age. Two of them produced sputum in the 24 hours before admission. They had no other distinguishing characteristics.

A subgroup of the most severe patients was separately analyzed; the patients who had a clinical score of 7 or greater were assessed. There were 7 severe patients in the placebo group and 7 severe patients in the physiotherapy group. Similar findings by clinical assessment and characteristics in the subgroups were noted and no statistical differences in lung function were found between the PT and placebo groups.

Of the 70 PT sessions, 49 (66%) were accompanied by productive cough. In only 18 (37%) of these 49 could sputum be collected; in the remainder sputum was either swallowed (28 treatments) or vomited (3 treatments). Sufficient sputum to be weighed was obtained in only 18/70 (26%) PT sessions. Sputum weights ranged from 0.7 to 10.8 g (3.6 ± 2.7 g).

The peak flow rate at the time of discharge from hospital was similar in the placebo (298 ± 87 L/min, $\bar{X}$ ± SD) and PT group (278 ± 87 L/min). The placebo group spent a longer period in hospital, a total of 20.8 days more, than the PT group (Fig. 2), although this difference was not statistically significant. The average duration of attack before admission added to the duration of hospital stay was the same in each group (7 days). All 3 placebo patients who remained in hospital for more than 7 days were 12 years old.

DISCUSSION

In children aged 6–13 years recovering from acute severe asthma, receiving asthma drug therapy, no statistically significant advantage on lung function of chest PT over placebo treatment has been found. However, improvements in expiratory flows at low lung volumes in 3 of the 19 children were greater in the PT group than those seen in the placebo group. These 3 children were 12 year old boys, not clearly distinguishable from other subjects. The duration of attacks before admission was on average shorter in the placebo group, and they stayed on average longer in the hospital than the PT group; those who stayed longest were 12 years old. Our results suggest that a trial of chest PT may be useful in older children recovering from acute severe asthma who are responding slowly to drug therapy alone.

This study was designed to evaluate chest PT within the first 3 days after admission for an acute attack. Whether continuing the study for longer or starting it later would have changed the outcome is not known. On retrospective calculation, the study had 99% power, at the 5% level, to detect a 10% higher final FEV_1 in the PT group compared with the placebo group, had such a difference existed; thus a type II error is most unlikely. The use of patients more than once reduces the variability of data which would theoretically increase the chance of finding a difference between groups. Since no difference was found, the inclusion of data from 3 children studied on 2 separate occasions (contributing only 8% of patient data) was unlikely to be misleading.

The chest PT techniques used in this study were chosen by an experienced physiotherapist to suit the patient's presentation, as occurs in usual clinical practice. Subjects predominantly underwent relaxation exercises and techniques to clear secretions. Clearance of secretions is believed to be most effective when postural drainage is combined with coughing[14] or forced expiration technique[7] as in this study. Movement of inflammatory exudate and mucus to proximal airways will be enhanced by these techniques. Effective clearance of this material might be associated with the improvement of expiratory flows at low lung volumes as seen in a minority of subjects in this study.

Although most subjects had productive cough we were not able to estimate daily sputum production because

TABLE 6—Lung Volumes and Flow Rates of Placebo Group[a]

	1A	1B	1C	4A	4B	4C
FVC (%)	84 ± 22	88 ± 22	88 ± 21	99 ± 18	100 ± 18	100 ± 18
FRC (%)	148 ± 23	143 ± 24	139 ± 21	134 ± 23	129 ± 22	132 ± 23
RV (%)	232 ± 51	212 ± 53	201 ± 50	181 ± 54	161 ± 52	169 ± 53
TLC (%)	121 ± 17	121 ± 17	118 ± 17	121 ± 15	119 ± 15	121 ± 13
PEFR (%)	74 ± 23	81 ± 22	79 ± 24	95 ± 26	100 ± 26	97 ± 29
FEV_1 (%)	65 ± 19	70 ± 19	70 ± 19	82 ± 22	87 ± 22	86 ± 21
FEF_{25-75} (%)	36 ± 17	40 ± 21	39 ± 20	50 ± 22	61 ± 26	59 ± 26
$\dot{V}_{max\ 50VC}$ (L/s)	1.52 ± 0.59	1.80 ± 0.60	1.80 ± 0.61	2.60 ± 1.13	2.90 ± 1.11	3.10 ± 1.39
$\dot{V}_{max\ 60TLC}$ (L/s)	0.79 ± 0.58	1.05 ± 0.58	1.00 ± 0.57	1.56 ± 1.08	1.83 ± 1.08	1.95 ± 1.20
$\dot{V}_{max\ 25VC}$ (L/s)	0.66 ± 0.28	0.82 ± 0.33	0.87 ± 0.35	1.42 ± 0.72	1.65 ± 0.88	1.78 ± 0.99

1st treatment
- 1A, before salbutamol
- 1B, 15 minutes after salbutamol
- 1C, after PT or placebo treatment

4th treatment
- 4A, before salbutamol
- 4B, 15 minutes after salbutamol
- 4C, after PT or placebo treatment

[a]All values: mean ± SD. (%), percent predicted.

TABLE 7—Lung Volumes and Flow Rates of PT Group[a]

	1A	1B	1C	4A	4B	4C
FVC (%)	79 ± 16	83 ± 15	85 ± 17	92 ± 21	93 ± 20	95 ± 19
FRC (%)	135 ± 15	125 ± 14	124 ± 11	129 ± 14	126 ± 18	126 ± 17
RV (%)	209 ± 53	173 ± 43	170 ± 39	172 ± 43	162 ± 44	159 ± 43
TLC (%)	114 ± 13	111 ± 12	113 ± 13	115 ± 15	114 ± 16	115 ± 16
PEFR (%)	71 ± 17	82 ± 15	81 ± 20	84 ± 19	92 ± 19	97 ± 16
FEV_1 (%)	64 ± 15	69 ± 17	71 ± 18	80 ± 20	84 ± 20	87 ± 18
FEF_{25-75} (%)	37 ± 14	44 ± 21	53 ± 40	53 ± 25	63 ± 20	67 ± 22
$\dot{V}_{max\ 50VC}$ (L/s)	1.49 ± 0.57	1.92 ± 0.59	2.25 ± 0.83	2.76 ± 1.21	3.36 ± 1.33	3.54 ± 1.21
$\dot{V}_{max\ 60\ TLC}$ (L/s)	0.73 ± 0.57	0.88 ± 0.50	1.13 ± 0.64	1.41 ± 0.94	1.83 ± 1.08	2.02 ± 0.86
$\dot{V}_{max\ 25VC}$ (L/s)	0.66 ± 0.31	0.97 ± 0.45	1.19 ± 0.57	1.61 ± 0.91	2.07 ± 1.00	2.20 ± 1.08

1st treatment
- 1A, before salbutamol
- 1B, 15 minutes after salbutamol
- 1C, after PT or placebo treatment

4th treatment
- 4A, before salbutamol
- 4B, 15 minutes after salbutamol
- 4C, after PT or placebo treatment

[a]All values mean ± SD. (%), percent predicted.

attempts at expectoration were often unsuccessful and the sputum was swallowed or vomited. When sputum was produced, it was a small amount (<11 g per treatment). Thus, it appears that asthmatic children may only produce a small amount of sputum, and that sputum collection is an inaccurate method for assessing mucus clearance from airways, as has been found in patients with cystic fibrosis.[5]

This study has not tested the benefits of PT for complicating conditions, such as lobar atelectasis, where it may be useful. We made no attempt to measure other parameters of patient function such as exercise tolerance, subjective sense of well being, breathlessness, relaxation, efficiency of breathing, gas exchange, fatiguability of muscles, and so on. The physiotherapist's role in drug delivery and education during acute asthma admissions was not evaluated either.

Chest PT on its own was not given in this study; it was given as an adjunct to standard drug therapy for acute asthma which included high doses of inhaled salbutamol, theophylline, and in 80% patients oral or parenteral steroid. All these drugs improve air flow limitation, and salbutamol and theophylline enhance mucociliary clearance.[8,9] In the face of these medications chest PT would have to have a strong effect to be seen above the effects of the drugs.

This study suggests that chest PT techniques do not improve lung function in most children aged 6 to 13

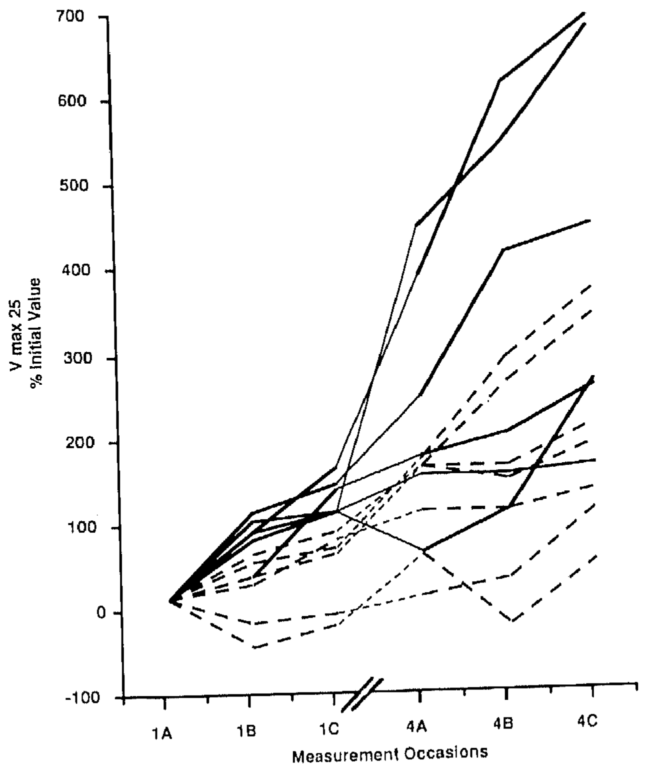

Fig. 1. $\dot{V}_{max\ 25VC}$ **for the 6 PT (solid lines) and 7 placebo patients (dashed lines) who showed improvement after both the first and fourth treatments.** $\dot{V}_{max\ 25VC}$ **is expressed as a percentage of initial value obtained at measurement 1A. First treatment: IA, before salbutamol; IB, 15 minutes after salbutamol; IC, after PT or placebo. Fourth treatment: 4A, before salbutamol; 4B, 15 minutes after salbutamol; 4C, after PT or placebo.**

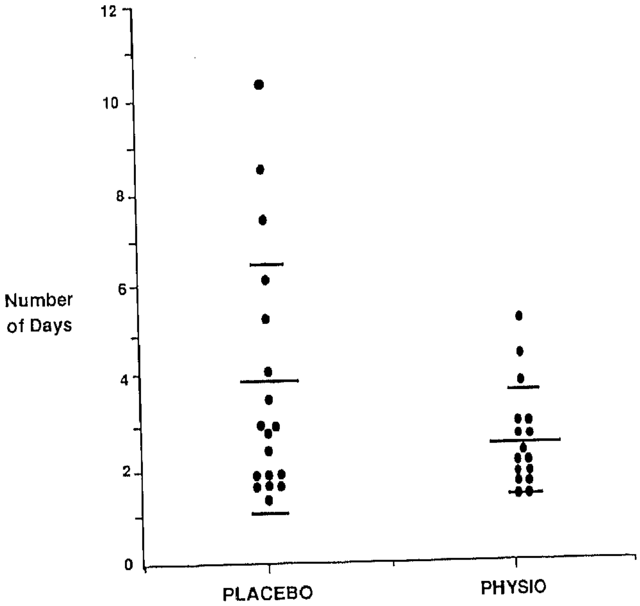

Fig. 2. Days spent in hospital; patients completing all 4 treatments. Mean and one standard deviation indicated by horizontal bars.

years admitted with acute severe asthma who receive asthma drug therapy. In a minority of older children chest PT may be of some benefit. With other patients physiotherapists can use their time most effectively by concentrating on other aspects of physiotherapy including inhaled asthma drug delivery, education, and patient support.

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