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Effects of Pulmonary Rehabilitation for Patients with Chronic Pulmonary Diseases with Different Types of Ventilatory Defects: Relationships between Pulmonary Function Parameters and Exercise Torelance

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This prospective cohort study was conducted to determine which pulmonary function parameters are useful in the prediction of exercise torelance and exercise-induced hypoxemia (EIH) among patients with chronic pulmonary diseases with different types of ventilatory defects. Fifty one patients with chronic pulmonary diseases who underwent comprehensive pulmonary rehabilitation for periods of 4 to 8 weeks, and who were classified as to different types of ventilatory defects; obstructive, restrictive and mixed type based on their pulmonary functions. All patients were measured for pulmonary function parameters, 6-minute walking distance (6MD) and the activity of daily living (ADL) before and after pulmonary rehabilitation. After pulmonary rehabilitation, the patients demonstrated a significant ($p<0.001$) increase in 6 MD and ADL scores for all types of ventilatory defects. In the relationship between 6 MD and pulmonary function parameters, the forced expiratory volume in 1 sec. ($FEV_{1.0}$) was significantly correlated with 6 MD for all types of ventilatory defect. Vital capacity (VC) and maximal voluntary ventilation (MVV) correlated with 6MD in the obstructive and the mixed ventilatory defects, and PaO_2 correlated with 6 MD relative to mixed ventilatory defects. In the relationship between EIH and pulmonary function parameters, VC significantly correlated with EIH relative to restrictive ventilatory defects. $FEV_{1.0}$ and MVV correlated with EIH relative to obstructive ventilatory defects. Our present data suggest that specific pulmonary function parameters which can be correlated with 6 MD and EIH for different types of ventilatory defects, may be useful in terms of devising pulmonary rehabilitation protocols for these patients.

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Abbreviations: 6MD=6-minute walking distance; EIH=exercise-induced hypoxemia; ADL=activity of daily living; $FEV_{1.0}$=forced expiratory volume in 1 sec.; FVC=forced vital capacity; VC=vital capacity; MVV=maximal voluntary ventilation; TB seq=sequela of pulmonary tuberculosis; SpO_2=arterial oxygen saturation by pulse oximetry; PI max=maximal inspiratory pressure; VO_2max=maximal oxygen uptake

Introduction

Two common types of chronic pulmonary diseases, such as chronic obstructive pulmonary disease (COPD) and restrictive lung diseases, are known[1)]. The restrictive lung diseases involve pulmonary fibrosis, pleural diseases including sequela of pulmonary tuberculosis (TB seq), and skeletal abnormalities[1]. With an increased number of elderly in the general population, the importance of pulmonary rehabilitation for chronic pulmonary diseases has been highlighted. However, the effectiveness of pulmonary rehabilitation for patients with chronic pulmonary diseases other than COPD has received less attention[2-7)]. No studies have been conducted relative to evaluating the effects of pulmonary rehabilitation for chronic pulmonary diseases which are associated with different types of ventilatory defects, although Foster, et al.[7)] recently reported that pulmonary rehabilitation is beneficial for patients with severe chronic pulmonary diseases other than COPD, as well as for patients with COPD.

Pineda, et al.[8)] demonstrated that maximum oxygen consumption was correlated with $FEV_{1.0}$ and MVV in patients with COPD. Furthermore, several studies[9-11] have previously reported that the evaluation of pulmonary function parameters is helpful in predicting which patients are likely to develop increasing hypoxemia during exercise in cases of COPD. However, little is known about the relationship between pulmonary function parameters and exercise tolerance or exercise-induced hypoxemia (EIH) among patients with chronic pulmonary disease who have different types of ventilatory defects. Such information may provide us with a better way to predict exercise capacity of these patients, and may be helpful in prescribing exercise training.

In order to determine the effects of pulmonary rehabilitation for patients with chronic pulmonary disease with different types of ventilatory defects, we evaluated the pulmonary function parameters, 6-minute walking distance (6MD) and activity of daily living (ADL) before and after pulmonary rehabilitation among these patients in this study. We also analyzed the relationships between pulmonary function parameters and 6 MD or EIH in order to determine which pulmonary function parameters are useful in predicting the exercise torelance and EIH of patients with a specific type of ventilatory defect.

Patients and Methods

Subjects

Fifty-one patients (33 male and 18 female; ranging in age from 32 to 84 year-old; mean age±SD: 68±12 year-old) with chronic pulmonary diseases were prospectively evaluated at Tagami Hospital, Nagasaki city, between 1991 and 1996. They were clinically stable during the period of study. Patients were admitted and then subjected to the comprehensive pulmonary rehabilitation including disease evaluation, educational programs as well as programming of exercise for a period of 4 to 8 weeks. The severity of breathlessness among these patients according to the definitions of Fletcher, et al.[12] were 10 in grade II, 24 in grade III, 12 in grade IV and 5 in grade V, respectively. Diagnostic groups included pulmonary emphysema (n=8), TB seq (n=16), pulmonary emphysema with TB seq (n=19), chronic bronchitis (n=2), bronchiectasis (n=1), radiation pneumonitis (n=1), status post lung resection (n=1), TB seq with pulmonary fibrosis (n=1), pneumoconiosis (n=1), and pneumoconiosis with TB seq and lung resection (n=1). Eleven patients received supplementary oxygen during exercise because of chronic respiratory failure.

Programming of pulmonary rehabilitation

The rehabilitation program consists of multiple components[2,4,13]; (1) an education program, (2) physical therapy including bronchial drainage, pursed-lip breathing, diaphragmatic breathing and relaxation techniques, (3) exercise conditioning regimens involving the stationary bicycle riding, floor walking, step walking, muscle training of the extremities[14] and ventilatory muscle trainin g[15,16]. Pulmonary function tests and 6 MD were examined, and the severity of breathlessness and ADL were assessed before and after pulmonary rehabilitation. ADL was assessed based on three parameters (velocity of motions, shortness of breath and oxygen demands) in daily activity with various grades of exertions including eating, defecation, face washing and brushing the teeth, bathing, dressing, walking in the room, walking in the ward, walking in the hospital, walking up the stairs, and shopping. Arterial oxygen saturation by pulse oximetry (SpO_2) was monitored for each patient during the 6 MD test.

Patients were classified into three groups; the obstructive type (n=15), the restrictive type (n=11) and the mixed type (n=22; obstructive and restrictive) of ventilatory defect. The obstructive and the restrictive type of ventilatory defect was defined when the the $FEV_{1.0}$/FVC % was less than 70% and when the percentage of predicted VC was less than 80%, respectively. The mixed type of ventilatory defect was defined by a combination of $FEV_{1.0}$/FVC % being less than 70% and the %VC being less than 80%.

Statistical analysis

Changes in pulmonary function parameters, the 6 MD and ADL score in patients with a specific type of ventilatory defect before and after pulmonary rehabilitation were compared by using Student's paired *t* tests. The data are presented as the mean±SD. Pearson's correlation coefficients were used to determine the relationships between pulmonary functions and 6 MD or EIH (the levels fall in SpO_2 in absolute values with 6 MD exercise) before pulmonary rehabilitation of different types of ventilatory defects. Significance was accepted if $p<0.05$.

Results

Regarding the effects of pulmonary functions, 6 MD and the ADL score before and after pulmonary rehabilitation were compared to patients with chronic pulmonary diseases with different types of ventilatory

Table 1. Comparison of pulmonary functions, 6 MD and ADL score among patients with chronic pulmonary diseases in different types of ventilatory defects before and after pulmonary rehabilitation.*

		Restrictive n=15	Obstructive n=11	Mixed n=22
VC (L)	Before	1.32±0.46	2.70±0.57	1.66±0.49
	After	1.61±0.50	2.59±0.54	1.90±0.62
	p	p < 0.05	NS	p < 0.005
$FEV_{1.0}$ (L)	Before	1.03±0.39	1.32±0.58	0.79±0.41
	After	1.14±0.39	1.30±0.57	0.83±0.42
	p	NS	NS	NS
MVV(L/min)	Before	35.0±12.4	49.5±26.6	25.6±11.1
	After	41.6±15.2	52.1±27.2	25.8±12.1
	p	p < 0.001	NS	NS
PaO_2 (mmHg)	Before	73.5±14.9	73.5±7.2	66.5±12.2
	After	76.8±14.3	75.4±8.8	69.0±11.1
	p	NS	NS	NS
$PaCO_2$ (mmHg)	Before	44.7±8.9	42.8±4.1	47.9±8.6
	After	45.0±7.2	41.4±4.6	47.4±7.0
	p	NS	NS	NS
PI max (cmH_2O)	Before	34.9±25.0	45.6±23.5	31.5±15.6
	After	46.7±29.5	57.5±31.8	46.7±23.8
	p	p < 0.05	NS	p < 0.01
6 MD (m)	Before	275.6±86.5	376.2±99.5	268.1±94.2
	After	347.8±86.3	427.7±91.4	313.7±78.3
	p	p < 0.001	p < 0.001	p < 0.001
ADL score	Before	72.0±19.4	81.2±8.1	59.0±21.4
	After	84.5±12.1	90.8±6.3	69.6±19.9
	p	p < 0.001	p < 0.001	p < 0.001

*Data represent the means±SD, NS = not significant.

Table 2. Correlation between 6 MD and pulmonary functions among patients with chronic pulmonary diseases in different types of ventilatory defects before pulmonary rehabilitation.*

	Restrictive		Obstructive		Mixed	
	r	p	r	p	r	p
VC	0.248	NS	0.686	p < 0.05	0.472	p < 0.05
$FEV_{1.0}$	0.572	p < 0.05	0.742	p < 0.01	0.507	p < 0.05
MVV	0.292	NS	0.716	p < 0.05	0.587	p < 0.005
PaO_2	0.174	NS	0.057	NS	0.760	p < 0.0001
$PaCO_2$	0.08	NS	0.544	NS	0.369	NS
PI max	0.613	NS	0.368	NS	0.595	NS

*r = coefficients of correlation; NS = not significant.

defects (Table 1). No differences in the values of $FEV_{1.0}$, PaO_2 or $PaCO_2$ were found before and after pulmonary rehabilitation. Significant increases in the values for VC and PI max, however, were observed in the restrictive ($p<0.05$ in VC and PI max) and in the mixed ($p<0.005$ in VC and $p<0.01$ in PI max) in ventilatory defects, but not in subjects with obstructive ventilatory defects. We also found a significant improvement in MVV only in the case of subjects with restrictive ventilatory defects ($p<0.001$). On the other hand, a significant improvement for the 6 MD and the ADL score was observed for all types of ventilatory defects ($p<0.001$). We next evaluated the relationship between 6 MD and pulmonary function parameters, for different types of ventilatory defects before pulmonary rehabilitation (Table 2). The $FEV_{1.0}$ value was significantly correlated with 6 MD in all types of ventilatory defects ($p<0.05$ in the restrictive type, $p<0.01$ in the obstructive type, $p<0.05$ in the mixed type). The clinical significance of $FEV_{1.0}$ as an exercise endurance index can, therefore, be confirmed[8,17-19]. We also found a significant correlation between 6 MD and VC or MVV in the obstructive and the mixed ventilatory defects ($p<0.05$; vs VC for both types and MVV in the obstructive type, $p<0.005$; vs MVV in the mixed type). It is noteworthy that the PaO_2 value at rest was highly correlated with 6 MD only in the case of mixed ventilatory defects ($p<0.0001$)(Fig. 1).

The benefit of oxygen supplementation during exercise in patients with EIH has been reported[20-22]. The relationships between EIH (the fall in the percent SpO_2) and pulmonary function parameters and arterial blood gases was investigated for the different types of vetilatory defects before pulmonary rehabilitation (Table 3). We also found significant correlations between EIH and VC in the case of restrictive ventilatory defects ($p<0.05$), and between EIH and $FEV_{1.0}$ or MVV in the case of obstructive ventilatory defects ($p<0.05$). No significant correlation between EIH and arterial blood gas tensions at rest was observed for any types of ventilatory defects.

Table 3. Correlation between exercise induced hypoxemia (the level fall in SpO_2 in absolute valuse with 6 MD exercise) and pulmonary functions among patients with chronic pulmonary diseases in different types of ventilatory defects before pulmonary rehabilitation.*

	Restrictive		Obstructive		Mixed	
	r	p	r	p	r	p
VC	0.765	p < 0.05	0.649	NS	0.413	NS
$FEV_{1.0}$	0.575	NS	0.847	p < 0.05	0.535	NS
MVV	0.415	NS	0.882	p < 0.05	0.463	NS
PaO_2	0.207	NS	0.443	NS	0.393	NS
$PaCO_2$	0.040	NS	0.756	NS	0.190	NS
PImax	0.523	NS	0.588	NS	0.511	NS

* r = coefficients of correlation; NS = not significant.

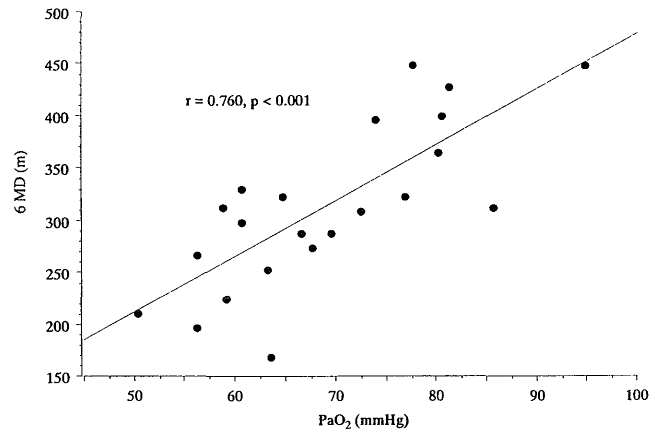

Fig. 1. Correlation between 6 MD and PaO2 levels at rest among patients with chronic pulmonary diseases with mixed ventilatory defects.

Discussion

Ambulation distance, as determined by 6 MD, is a simple exercise test that has been used in a number of previous studies as measure of exercise capacity, and has been shown to correlate with maximum oxygen uptake (VO_2max) in patients with COPD[23, 24]. The performance of this test depends on several factors, including endurance, respiratory function, cardiovascular fitness, neuromuscular function, motivation, encouragement, and practice[18,23,25]. In this study, we demonstrated a significant improvement in 6 MD and ADL as a result of pulmonary rehabilitation among patients with chronic pulmonary diseases with any type of ventilatory defect. Pulmonary rehabilitation improved VC and MVV to some extent, but the improvement in VC and MVV did not correlate with 6 MD (data not shown). Previous studies[26-29] have reported that pulmonary rehabilitation results in significant improvement in physiologic exercise tolerance in contrast to those of pulmonary function for patients with COPD. In addition, Casaburi, et al.[29] have described that patients with COPD are able to achieve a physiologic training effect, as manifested by a reduction in blood lactates and ventilation at given level of exercise. These findings are consistent with the improvement in 6 MD and ADL of patients with chronic pulmonary diseases in this study. We next examined the relationship between pulmonary function parameters and an initial 6 MD for patients with chronic pulmonary disease with different types of ventilatory defects (Table 2). The $FEV_{1.0}$ value correlated significantly with 6 MD for patients with each type of ventilatory defect. A highly significant correlation was found especially in patients with the obstructive type of ventilatory defect. Several investigators have previously reported a relationship between exercise tolerance and pulmonary function parameters[8,17-19]. Jones et al.[17] reported correlations between the maximal work load and $FEV_{1.0}$, VC, airway resistance and DLco in patients with chronic airway obstruction. ZuWallack et al.[18] similarly reported that the initial 12 MD correlated with FVC, $FEV_{1.0}$, peak VO_2 and peak PaO_2 in patients with chronic pulmonary diseases. Furthermore, $FEV_{1.0}$, VC and MVV values were significantly correlated with 6MD both in patients with the obstructive type and the mixed type of ventilatory defect in this study. This fact suggests that a limitation on ventilation is closely associated with exercise endurance in these patients. More interestingly, the levels of PaO_2 correlated with 6 MD for patients with chronic pulmonary diseases in the mixed type of ventilatory defect, although the specific reason for this remains unresolved. These data suggest that it may be possible to predict exercise tolerance in each patient with a certain type of ventilatory defect by examining pulmonary function tests and arterial blood gas prior to the start of pulmonary rehabilitation.

Breathing of supplemental oxygen improves exercise performance in patients with severe COPD[20-22]. An indication of the need for O_2 supplementation during exercise should be based on finding relative to exercise tests rather than on resting hypoxemia alone[9]. Patients with a resting arterial oxygen tension of less than 55 mmHg as well as patients with arterial desaturation during exercise are recommended to receive oxygen therapy[30]. Recent studies[10,11] have shown that some indexes which are helpful in determining which patients include desaturated during exercise. Owens, et al.[11] have reported two indexes of diffusing capacity and $FEV_{1.0}$ are predictive of desaturation in patients with COPD. However, no reports have been conducted on the relationship between EIH and pulmonary function parameters for cases of chronic pulmonary diseases with different types of ventilatory defects. In this study, we found significant correlations between EIH and VC in the restrictive type, and EIH and $FEV_{1.0}$ or MVV in the obstructive type of ventilatory defect, respectively (Table 3). These pulmonary function parameters, which correlate with EIH are important as limiting factors in patients with chronic pulmonary disease who have restrictive and obstructive types of ventilatory defects, while many parameters did not correlate with EIH, in terms of the mixed type of ventilatory defect. This may be explained by circulatory insufficiency through pulmonary arterial vasoconstriction, since a low arterial blood oxygen pressure was found in these cases ($PaO_2 \leqq 60$ mmHg in 7 cases and $PaO_2 \leqq 70$ mmHg in 14 out of 22 cases)[31,32]. Therefore, each pulmonary function parameter which correlates with EIH in different types of ventilatory defects is also valuable for predicting arterial oxygen desaturation during exercise for patients with chronic pulmonary diseases.

In summary, a comprehensive pulmonary rehabilitation is clearly effective in patients with chronic pulmonary diseases which have any type of ventilatory defect. We also found certain specific pulmonary function parameters which were correlated with exercise torelance or EIH for patients with chronic pulmonary diseases with different types of ventilatory defect. These observations support the conclusion that the evaluation of pulmonary function parameters may lead to a prediction of exercise torelance and EIH in patients with chronic pulmonary diseases with different types of ventilatory defect. We wish to emphasize that the initial assessment of pulmonary function parameters is essential for patients who receive pulmonary rehabilitation. Further studies will be required for the development of individual plans for pulmonary rehabilitation.

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