Exercise in patients with chronic obstructive pulmonary disease

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Summary

Patients with chronic obstructive pulmonary disease (COPD) may incur exercise limitation by any one or combination of disturbances in breathing mechanics, oxygen transport, respiratory muscle metabolism or respiratory regulation and sensation. In spite of the increased ventilation demand/capacity ratio in these patients, the relationship between breathing mechanics, respiratory muscle fatigue, the adequacy of alveolar ventilation and the development of exertional dyspnoea is neither clearly defined nor predictable from data obtained with the patient at rest.

The issue of oxygen transport during exercise has been complicated by confusion between arterial hypoxia and inadequate volume of oxygen transported to the tissues, which frequently may differ qualitatively and quantitatively. The cardiac output response to exercise in patients with COPD is therefore critical in determining oxygen transport. This response is also impossible to predict from resting lung mechanics, pulmonary arterial blood pressure, arterial oxygen tension or clinical disease profile. Without exercise testing, which includes measurement of all the variables mentioned, it is impossible to define clearly the cause of exercise-induced symptoms in patients with COPD. Exercise training with and without supplemental oxygen has been shown to improve exercise tolerance in these patients, but the precise mechanism of this improvement remains obscure.

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TABLE IV. INSTANCES WHERE ADVICE WAS FOLLOWED OR WHERE USEFUL ACTION RESULTED

| Domiciliary assessments by community nursing personnel, social workers and paramedical personnel | 8 |
|Applications initiated for suitable placements | 6 |
|Geriatric assessments carried out | 6 |
|Psychogeriatric assessments carried out | 2 |
|Relevant information known to have assisted | 2 |
|Successful introductions to Stroke Club | 2 |
|Advice assisted out-of-court settlement of a contested will | 1 |
|Relatives put into contact with British facilities | 1 |
|Assisted in getting monthly rates of an old-age home raised gradually | 1 |
|Placement found for elderly tenants in house bought for renovation | 1 |
|Total | 30 |

TABLE V. ANALYSIS OF SOURCES OF ENQUIRY

<table>
<thead>
<tr>
<th>No.</th>
<th>Enquiries by family carers</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>Enquiries by medical practitioners</td>
</tr>
<tr>
<td>10</td>
<td>General practitioners</td>
</tr>
<tr>
<td>5</td>
<td>Specialists</td>
</tr>
<tr>
<td>5</td>
<td>Elderly persons seeking information or assistance for themselves</td>
</tr>
<tr>
<td>6</td>
<td>Friends</td>
</tr>
<tr>
<td>3</td>
<td>Lawyers</td>
</tr>
<tr>
<td>2</td>
<td>Social worker</td>
</tr>
<tr>
<td>1</td>
<td>Total</td>
</tr>
<tr>
<td>50</td>
<td></td>
</tr>
</tbody>
</table>

obtaining relevant assistance, and this appears to date to have been the most effective function of our information centre.

I should like to thank Mrs E Gunston for her enthusiastic guidance and inspiration and the Cape Peninsula Organization for the Aged for its material assistance in producing the information manuals.

REFERENCES

1. Gunston E, Meiring PdV. Information Manual of Services Available to the Aged in the Cape Peninsula. 1st ed. Cape Town: Geriatric Unit, Department of Medicine, University of Cape Town and Cape Peninsula Organization for the Aged, 1983.
2. Gunston E, Meiring PdV. Information Manual of Services Available to Seniors in the Cape Peninsula. 2nd ed. Cape Town: Geriatric Unit, Department of Medicine, University of Cape Town and Cape Peninsula Organization for the Aged, 1984.
Exercise in the normal subject and especially in the patient with latent or clinically overt coronary artery disease has received considerable attention both in the lay and in the medical press. On the other hand the consequences of exercise in patients with the equally prevalent chronic obstructive pulmonary disease (COPD) have been neglected. At a time when regular exercise is frequently prescribed for patients with a variety of medical and non-medical conditions, it is important that the response of this group of patients to the stress of exercise be known to both medical and paramedical practitioners.

The single common factor which unites patients with COPD is expiratory airflow limitation. Diseases conventionally included within this 'dumping disease' are chronic obstructive bronchitis and emphysema. Asthma may also be included, depending upon the prejudice of the practitioner, but exercise-induced asthma is not the subject of this review. The exertional capacity of patients with COPD may be limited by any single factor or combination of disturbances in breathing mechanics, oxygen transport, the pulmonary and/or systemic circulation, respiratory muscle metabolism and, finally, respiratory regulation and sensation. It is an anomaly of current practice when evaluating dyspnoic syndromes, or prior to prescribing exercise protocols, to examine patients at rest in the recumbent position. Generally, little attention is given to evaluation of the cardiovascular reserve by means of exercise testing. Such testing may be beyond the scope of the GP, but is also a surprisingly infrequent part of the examination in teaching institutions. Even so-called stress tests seldom involve analysis beyond that of the ECG. There is a high incidence of COPD in this country, and since it shares common actiological factors with coronary artery disease, these conditions may coexist in the same patient. It is worth while, therefore, to review some of the features of the exercise response in this group of subjects.

**Normal response to exercise**

An exhaustive review of the physiological response to exercise will not be attempted, only a brief survey of the major cardiorespiratory adaptations: exercise requires an increased consumption of oxygen \( \text{O}_2 \) for the production of the adenosine triphosphate required by the working muscles. Also produced in the course of substrate oxidation is carbon dioxide \( \text{CO}_2 \) which has to be eliminated by expiration into the atmosphere. Although the cardiovascular and respiratory systems may be considered as a functional unit, the exertional responses may be usefully, although somewhat simplistically, viewed as follows: it is the primary role of the respiratory system to ventilate \( \text{CO}_2 \) into the atmosphere, while the function of the cardiovascular system is to deliver \( \text{O}_2 \) to the tissues. These two systems are obviously interdependent, being united at the pulmonary gas exchange interface where \( \text{O}_2 \) transfer across the alveolar capillary membrane is potentially more problematical than \( \text{CO}_2 \) diffusion.

For any given level of \( \text{CO}_2 \) production, the alveolar ventilation and arterial \( \text{CO}_2 \) pressure \( (\text{Paco}_2) \) bear a reciprocal relationship. It is necessary for ventilation to keep pace with the level of \( \text{CO}_2 \) production so that the \( \text{Paco}_2 \) remains constant. In response to the increased \( \text{CO}_2 \) production on exercise, ventilation also increases, initially by means of tidal volume changes followed at higher levels of exertion by increases in the rate of breathing. Inadequate ventilation leads to hypercapnia, a reciprocal decline in arterial \( \text{O}_2 \) pressure \( (\text{Pao}_2) \) and respiratory acidosis. Hyperventilation obviously has opposite effects.

With regard to the delivery of \( \text{O}_2 \) to the tissues in the face of the increasing demands of exertion, it is significant that the \( \text{O}_2 \) content in the arterial blood does not materially increase because of both the slope and shape of the oxyhaemoglobin dissociation curve and the relative constancy of the \( \text{Pao}_2 \). The burden of delivering more \( \text{O}_2 \) to the tissues per unit time therefore falls on the cardiac output, which increases in a linear fashion with increase in \( \text{O}_2 \) consumption. To effect this increase in cardiac output, there are increases in the heart rate (the major mechanism) and stroke volume. The latter is mediated by increased preload (venous return) due to arterial vasodilation and increased action of the venous muscular pump; the afterload (in essence the diastolic blood pressure) is either constant or declines slightly on dynamic exercise while the contractility of the heart increases. With increasing fitness the stroke volume response to exercise increases, i.e. there is a lower pulse rate at a given exercise load.

A further consequence of the increased \( \text{O}_2 \) demand in exertion is increased \( \text{O}_2 \) extraction from the blood, resulting in a reduced venous \( \text{O}_2 \) pressure \( (\text{Pvo}_2) \). This latter value, considered to reflect tissue \( \text{Pao}_2 \) must be interpreted in the light of the exercise-induced increase in capillary density in the metabolically active tissues. A decline in \( \text{Pvo}_2 \) does not therefore necessarily imply a reduced tissue \( \text{Pao}_2 \).

**Response to exertion in patients with COPD**

Breathing

Since patients with COPD have expiratory airflow limitation they all have a reduced ventilatory capacity; in view of the increased work of breathing, augmented in some cases by increased alveolar dead-space due to pulmonary vascular curtailment, there is also increased ventilatory requirement. These considerations have led to the generally accepted hypothesis of an increased demand/capacity ratio causing a ventilatory limitation of exertion. The nature of any such ventilatory limitation, however, is not clear: although respiratory muscle fatigue has been implicated, hypventilation on exercise is uncommon. Hyperventilation in COPD patients whose \( \text{Pao}_2 \) declines on exercise has also recently been described. The exertional dyspnoea in this group of patients, therefore, does not appear to be clearly related to the adequacy of alveolar ventilation. Stimulation of local chemoreceptors in conditions of respiratory muscle fatigue may be responsible for the dyspnoea. Another possibility is mechanoreceptor stimulation caused by breathing from an increased or decreased functional residual capacity. There is evidence that breathing exercises, i.e. respiratory muscle training, are of some value in relieving exertional dyspnoea.

Although dyspnoea may be a dominant symptom at maximal exercise in patients with COPD, it does not necessarily follow that the mechanical defect of ventilation is in fact the physiological reason for limited exercise tolerance. It has recently been shown that in patients with excessively high ventilatory demand/capacity ratios: (i) the minute volume was often excessive (accompanied by hypocapnia) and associated with a decline in \( \text{Pao}_2 \); and (ii) there was often an associated low cardiac output response to the exercise.

**Oxygen transport**

COPD is usually accompanied by ventilation-perfusion \( (V/Q) \) mismatching. In chronic obstructive bronchitis there is significant pulmonary blood flow to poorly ventilated alveoli (low \( V/Q \)); in patients with emphysema, however, there are relatively few low \( V/Q \) areas and the dominant defect is that of a high \( V/Q \) ratio. A low \( V/Q \) situation leads to the incomplete oxygenation of the venous blood and results in arterial hypoxia (the 'blue bloater'), whereas a high \( V/Q \) ratio results in alveolar dead-space which increases the ventilatory requirement. The \( V/Q \) relationship during exercise has not been established clearly — it may stay constant, improve or deteriorate. Venous blood desaturation is inevitable during exercise and, in the face of a significant degree of venous admixture, will lead to arterial hypoxia. It is impossible to
predict at rest which patients with COPD will develop exertional hypoxia, although this appears to be more common in the more severely affected individuals.\textsuperscript{1,2}

Apart from the arterial hypoxia which may accompany exercise, there is the possibility of a low cardiac output response in patients with COPD.\textsuperscript{13} This will result in a disproportionately reduced convective flow of \textit{O}_2 to the tissues, a consequently greater \textit{O}_2 extraction from the blood and an aggravated venous desaturation. The presence of carboxyhaemoglobin from smoking assumes heightened significance in this group of patients through its effect of blocking \textit{O}_2 binding sites on haemoglobin, further limiting exertional capacity.\textsuperscript{14}

Erythrocytosis is a feature of severe COPD. It appears that the benefit in terms of increased \textit{O}_2-carrying capacity outweighs the relatively insignificant deleterious consequence of increased peripheral vascular resistance, secondary to the increased viscosity of the blood.\textsuperscript{15} When therapeutic venesection is planned, it is imperative to be aware of the cardiac reserve of the patient since the only mechanism by which convective \textit{O}_2 flow can be maintained in the face of a decline in the haemoglobin value is by increasing cardiac output. Some patients have such severe pulmonary hypertension and deranged lung mechanics that a more vigorous exertional cardiac response is precluded, and in these subjects venesection is potentially dangerous.

### Cardiopulmonary haemodynamics

The relationship between arterial desaturation and pulmonary artery pressure is well established, as is the association between the development of cor pulmonale and pulmonary hypertension.\textsuperscript{15} The nature of the cardiac response to exercise in patients with COPD is not clearly understood. It has been held that patients with emphysema have a poor cardiac response, while those with chronic bronchitis are usually considered to have a normal response.\textsuperscript{13} This contention would seem to be contrary to the association between arterial hypoxia, pulmonary hypertension and cor pulmonale. In a recent study it was not possible to confirm the current hypothesis,\textsuperscript{8} since patients with the clinical and functional features of emphysema were equally divided between subjects who had a normal cardiac output response and those with a low output on exertion. There was no difference in the degree of resting or exertional pulmonary hypertension in the two latter groups. Expiratory airflow limitation and lung hyperinflation were greater in the low cardiac output group. It was impossible, however, to predict with certainty the cardiac output response of the subjects from any resting measurements.

Although the relationship between arterial oxyhaemoglobin saturation and pulmonary artery pressure is well established, it can mask the basic difference between the patients who do and do not develop exertional hypoxia relative to resting oxygenation. Those patients whose \textit{PaO}_2 declines on exertion presumably have a pulmonary vasculature which is more compromised, since the pulmonary artery pressure increases markedly per unit increase in cardiac output. In the patients whose \textit{PaO}_2 does not fall on exercise, the pulmonary vascular resistance declines in spite of the increase in pulmonary artery pressure, even at moderate grades of exercise.\textsuperscript{6} This has considerable clinical relevance since Fei et al.\textsuperscript{16} have shown that an exertional elevation of pulmonary vascular resistance is associated with a high mortality in thoracic surgery.

### Exercise training

Patients with COPD tend to improve their exercise tolerance after training, even at low work rates.\textsuperscript{10} Although a target heart rate of 70% of the predicted maximum is desirable, this may not be achieved in patients with COPD, who frequently have a resting tachycardia. Respiratory muscle fatigue has been shown to influence exercise tolerance in COPD,\textsuperscript{3} and it would seem logical that respiratory muscle training may have a role to play in the overall rehabilitation of certain patients, although it is not essential for the general benefit of a conventional training programme in patients with COPD.\textsuperscript{10} It is of interest that the benefits of exercise training in patients with COPD are not associated with changes in pulmonary function test results, blood gases or haemodynamics.\textsuperscript{5} It has further become established that supplemental \textit{O}_2 therapy during training in severely disabled patients is beneficial, and may lead to further improvement in exercise tolerance.\textsuperscript{5}

### Conclusion

It is clear that the pathophysiology of the exercise response in patients with COPD is not a simple matter, and in terms of individual subjects it would appear to be totally unpredictable from data obtained at rest. In the most general terms, it can be stated that in the presence of severe airflow limitation and lung hyperinflation, the exercise response has a greater likelihood of becoming associated with arterial hypoxia, pulmonary artery hypertension, poor cardiac output and a severe limitation of exercise tolerance.\textsuperscript{8} There remains, however, a need to assess each patient individually, in order to plan therapy and direct it towards the dominant pathophysiological problem. When patients complain of exertional dyspnoea it is desirable, if not essential, for medical practitioners to subject the patient to an exercise test. This is especially true in dyspnoea of uncertain origin. When exercise tests are performed, it is imperative that the arterial blood gases should be measured directly or indirectly, while measurement of the pulmonary artery pressures, mixed venous blood and cardiac output is often extremely useful. In view of the complexity of exercise responses, it is perhaps time that exercise tests were performed more frequently in dyspnoeic patients, since conventional static lung function tests and stress ECGs are unable to predict the pathophysiological adaptations to exertion. Knowledge of the latter may well play an important role in determining therapy, in assessing fitness for thoracic surgery, and in estimating the prognosis of the patient.

### REFERENCES


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