PULMONARY LIMITATIONS TO PERFORMANCE IN SPORT

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Rowing requires high ventilatory capacity.

Assuming lung function to be normal, there is said to be no pulmonary limitation to aerobic performance. Justification for this statement rests with the fact that, while exercising at the maximum aerobic capacity (that is, when the rate of oxygen consumption cannot be further increased ($\text{VO}_{2\text{max}}$)), it is possible to increase ventilation still more by voluntary effort. The main limiting factor is held to be a failure to match the rate at which muscle can consume oxygen with the rate at which oxygenated blood can be delivered; in other words, the cardiac output.

The lungs may be regarded as the carburettor of the engine, thus only when they are diseased—such as in chronic bronchitis or emphysema—does ventilatory capacity become reduced to the point where it limits exercise tolerance. Chronic bronchitis causes obstruction to air flow which, coupled with a reduction in vital capacity, results in a low ventilatory capacity or minute volume. Emphysema imposes an additional burden because not only is minute volume reduced but so also is oxygen transfer because of a loss of alveoli.

Importance of high ventilatory capacity

High ventilatory capacity is essential for sports such as rowing, cycling, and middle and long distance running. When exercised to maximum most elite athletes in their mid-20s reach a respiratory rate of around 55 breaths a minute with a heart rate of close to 200, regardless of their size. In absolute terms the highest minute ventilation is usually achieved by the biggest athletes, as breath volume is directly related to size. Indeed the highest so far measured at the British Olympic Medical Centre is 245 l/min clocked up by a male heavyweight rower. The same is also true of peak oxygen consumption, with the biggest athletes recording up to 8 litres of oxygen consumed a minute and an average around 5.26 min.

A more objective measure of aerobic performance is reached by removing the variability introduced by size by dividing by body weight. The minute ventilation of elite male track athletes is then about 2.7 l/kg/min with a maximum oxygen consumption of around 79 ml/kg/min. The relation between maximum aerobic capacity and minute ventilation is roughly linear. In other words people with the highest aerobic capacity tend also to achieve the highest minute ventilation.

Minute ventilation (VE) at maximum oxygen consumption ($\text{VO}_{2\text{max}}$) in 120 olympic class athletes. Those with the highest VE (male rowers) also have the highest ($\text{VO}_{2\text{max}}$) because they are the biggest. When the size factor is removed male track athletes score highest.

Airflow obstruction limiting performance

Exercise can induce asthma.

Minute ventilation is limited in respiratory diseases characterised by obstruction to air flow. Chronic obstructive airways disease may cause such severe ventilatory impairment that exercise tolerance is judged only by the distance covered when walking briskly on level ground for 10 or 12 minutes.

For athletes, asthma causing airflow obstruction holds a position of great importance because it is a common complaint. Of all those attending the British Olympic Medical Centre last year with underperformance not attributable to injury, around 20% blamed their poor performance on respiratory symptoms. But asthma is important for other reasons: obstruction to airflow can be brought on by exercise itself, and the reduced ventilatory capacity can readily be improved with treatment, thereby transforming performance.

Diagnosis of asthma

A history of cough or wheeze after exercise and particularly of sleep disturbance due to tightness in the chest should arouse suspicion. Diagnostic proof rests with showing an obstruction to air flow that is variable, so a minimum of two estimations of peak flow or FEV₁ (forced expiratory volume in one second) taken at different times of the day is needed. For normal subjects the variation in peak flow is seldom more than 8%, with the lowest measurement recorded usually first thing in the morning. Differences of more than 20% in values obtained at any time during the day is strongly suggestive of asthma.

Flow loop spirometry is performed with the subject breathing out forcibly from full inspiration to full expiration, giving forced vital capacity (FVC).

Exercise induced asthma in a track athlete. The flow loops measured before and 10 minutes after vigorous running show the typical changes with reductions of more than 15% in both peak expiratory flow and forced vital capacity. The peaking and sagging of the downward limb are important diagnostic signs. The sagging results in a bigger percentage fall in flow when both 50% and 25% of forced vital capacity remains to be expired (F₅₀ and F₂₅ respectively) than in FEV₁. In this instance FEV₁ fell 40% but F₅₀ fell by 60% and F₂₅ by 65%.

Exercise testing for asthma

Running in the open air can cause bronchial constriction.

There is no agreed standard test protocol for inducing asthma with exercise, but certain ingredients are important. Running in the open air is a more potent stimulus to bronchial constriction than exercising on a bicycle or treadmill ergometer. The reasons for this are complex and are related in part to climatic conditions. Cold dry air causes more bronchial constriction than warm moist air. The exercise must be vigorous, sufficient to raise the heart rate to around 80% of the maximum that can be achieved (220 minus age in years).

The duration of the test is also important. It should last at least three minutes but not much longer than five. Either peak flow or FEV₁ can be measured with readings taken immediately before and at five and 10 minutes after the run. Normal subjects may show a short lived bronchial dilatation on stopping, but a fall of 15% or more from pre-test values is a positive result.

International Olympic Committee's Medical Commission's rules on antiasthma drugs

Drug class	Banned	Permitted (by inhalation only)
Corticosteroids	All oral, intramuscular (depot), or intravenous preparations	Budesonide (Pulmicort) Beclomethasone (Becotide)
Selective β adrenoceptor stimulants	All oral, depot, or intravenous preparations and fenoterol (Berotec) inhalation	Salbutamol (Ventolin) Terbutaline (Bricanyl) Pirbuterol (Exirel) Rimiterol (Pulmadil) Salmeterol (Serevent)
Non-selective adrenoceptor	Ephedrine Isoprenaline (Medihaler)	Orciprenaline (Alupent) stimulants
Antimuscarinic bronchodilators	None	Ipratropium (Atrovent) Oxitropium (Oxivent)
Cromoglycate preparations	Cromoglycate with isoprenaline (Intal compound)	(Intal) (Nedrocromil)
Theophylline	None	

Effective treatment of airflow obstruction undoubtedly improves performance. However, some athletes have unrealistic expectations. Paradoxically the greatest problems arise when an individual has been given treatment for which there is no indication. The problem then becomes one of withdrawing medication. Selecting a drug regimen that will not violate the doping regulations of the International Olympic Committee (IOC) is crucial. As a rule of thumb, all systemically acting antiasthma drugs are banned whether taken by mouth or parenteral injection, the only exception being aminophylline.

The mainstay of treatment in asthma, of which exercise induced bronchial narrowing is a symptom, is corticosteroids by inhalation. Both budesonide and beclomethasone are permitted, and the dose should not exceed 1600 μg a day. Powdered preparations are longer acting than metered dose inhalers and effective when taken morning and evening. Bronchodilators form an adjunct to inhaled steroids and are best taken around 10 minutes before competition. Selective β agonists such as salbutamol and terbutaline are permitted, but fenoterol is banned. Bronchodilators with a stimulant properties such as adrenaline and isoprenaline are also banned.

Severe bronchoconstriction induced by exercise. Both peak flow and forced vital capacity are greatly reduced. (Oscillations in the expiratory flow loop are the result of coughing.) After prednisolone 30 mg a day for two weeks the bronchoconstriction had been almost eliminated.

Sodium cromoglycate inhibits exercise asthma if taken about 10 minutes before competition and is especially effective in children. The combination of cromoglycate with isoprenaline is a banned substance and must not be used.

Caveat

At present any athlete is able to obtain antiasthma medication and is allowed to inhale any amount that he or she pleases. There is no obligation to provide medical evidence of respiratory disease. As a result, some athletes are taking medication only because they have been told by fellow competitors that it improves performance. I have seen one who was in the habit of taking 20 puffs from a salbutamol inhaler before each race. The IOC Medical Commission has yet to rule on this issue, and until it does the situation will remain unsatisfactory.

The photograph of the women's coxless four in the Olympic regatta at Bayolas, Spain, in 1992 was taken by Peter Spurrier, Sports Photography; that of Liz McColgan in the 10 000 m heats at the Barcelona Olympics in 1992 by Professional Sport; and that of a step aerobics class by Richard J Sowersby.

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