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An Overview of Physiological Basis of Exercise Training in Pulmonary Rehabilitation

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Abstract: ***Pulmonary rehabilitation is a comprehensive intervention for patients suffering from various chronic respiratory diseases, aimed at improving the functional outcome and improving the quality of life. Exercise training is the only way to improve cardiorespiratory endurance and muscle strength which will improve the quality of life of patients. Knowledge about exercise physiology helps in prescribing exercise according to the individual need and capability.***

Keywords: Pulmonary rehabilitation, exercise physiology, pulmonary adaptations, exercise training principles

1. Introduction

Pulmonary rehabilitation is a comprehensive intervention for patients suffering from various chronic respiratory diseases, aimed at improving the functional outcome and improving the quality of life. It is defined as “A comprehensive intervention based on a thorough patient assessment followed by patient tailored therapies that include, but are not limited to, exercise training, education, and behaviour change, designed to improve the physical and psychological condition of people with chronic respiratory disease and to promote the long - term adherence to health - enhancing behaviours.” By ATS/ETS 2013.

However, exercise training is considered to be the ‘corner stone’ of pulmonary rehabilitation, as it is the only way to improve cardiorespiratory endurance and muscle strength which will benefit the patient to overcome the dyspnoea and fatigability while processing the activities of daily living (ADL).

Why is it important to know the exercise physiology? And the answer is, a good result in exercise training depends on various physiological adaptations of human body in response to exercise training.

Chronic respiratory diseases are characterised by Low VO_2max, low anaerobic threshold, low pulmonary reserve, tachypnea, CO_2 retention etc. Aim of a structured rehabilitation programme is to improve all these parameters finally increasing the functional capability of the patient.

2. Exercises in Pulmonary Rehabilitation

- Cardiorespiratory Endurance Training
- Strength And Muscle Training (Resistance Training)
- Flexibility Training

Table 1: Difference between Endurance Training & Resistance Training

Endurance Training	Resistance Training
a) Large muscle groups are used continuously b) Improves the aerobic capacity Examples: • Walking • Treadmill • Stationary bicycle • Sit and stand etc.	a) Local muscle groups are trained by repetitive lifting of relatively heavy loads b) Increases skeletal mass/strength c) Induces less dyspnoea than endurance training Examples: • Exercise with Dumbbell, theraband etc.

Exercise Training Principles

These principles helps to describe the physiological basis for Structural and functional adaptations to improve performance in specific physical tasks after exercise training. Both men and women respond and adapt to training in essentially similar ways with individual variations. Now let us look into the various training principles.

1) Overload Principle

- It states that exercising at intensities greater than normal regularly stimulates highly specific adaptations so the body can functions more efficiently.
- It is achieved by manipulating training frequency, intensity, and duration, or a combination of these factors.
- This principle applies to both normal/ diseased individuals

2) Principle of Specificity

It states metabolic responses to exercise occur most specifically in those muscle groups being used & the types of adaptation will be reflective of the mode and intensity of exercise. Hence it can also Specific Adaptations to Imposed Demands (SAID) principle.

Examples:

- In Aerobic exercise there is an increase in both mitochondria &capillary density in muscle
- where as in resistance exercise there is an increase in muscle contractile proteins
- A running exercise program cause no adaptation in arm muscles.
- Distance running training utilizing low - intensity muscle fibre there is no adaptation in fast - twitch fibres

- One of most frequently encountered question by patient to doctor in the OPD is "why should I do separate exercise when I have enough house chores to do?"

Above both principles is the best explanation you can ever give to your patient.

3) Periodization Principle
This principle reflects the importance of incorporating adequate rest between training programme to accompany harder training bouts.

4) Individual Differences Principle
All individuals do not respond similarly to a given training stimulus and this principle gives the reason. eg. During training it's noticed that Individuals with lower fitness deliver the greatest training improvements.

5) Reversibility Principle
This principle is one that we should always remember as a rehabilitation physician which stresses the importance of maintenance phase in every rehabilitation programme.

Few weeks of detraining reduces both metabolic and exercise capacity gained during training period, fully lost subsequently. Even in highly trained athletes physiological gains are lost after a period of detraining.

Physiological Adaptations in Exercise Training

Table 2: Neural Adaptation and Muscle hypertrophy

Neural Adaptation	Muscle hypertrophy
• Adaptation that occur within the first few weeks of training • Recruitment of larger motor units in response to need • Responsible for Initial gains as in Inpatient rehabilitation of short duration	• Occurs After 6 to 7 weeks of resistance training • Increase of total muscle mass and cross - sectional area. • More common in fast - twitch than in slow - twitch muscles. • Increase in muscle contractile protein synthesis/ myofibrils split resulting in more myofibrils • Fibre hyperplasia (rarely) • Addition of new sarcomeres

Regarding muscle fiber adaptations, there is an increase in stored muscle glycogen, Selective hypertrophy of fast or slow twitch fiber with No change in Percentage of fast and slow - twitch muscle fibers.

Metabolic Adaptations

Mitochondria
- Increase in Number & size → increased capacity to generate ATP aerobically
- Helps to maintain prolonged effort during training without blood lactate accumulation

Fat Metabolism
- Increases the oxidation of fatty acids for energy
- Conserves the glycogen reserve, important during prolonged, intense effort

Carbohydrate Metabolism
- Increased capacity to oxidize carbohydrate during maximal exercise
- Provides further resistance to hypoglycaemia during prolonged physical activity

Cardiovascular Changes
The figure below summarizes the cardiovascular adaptations in response to exercise training

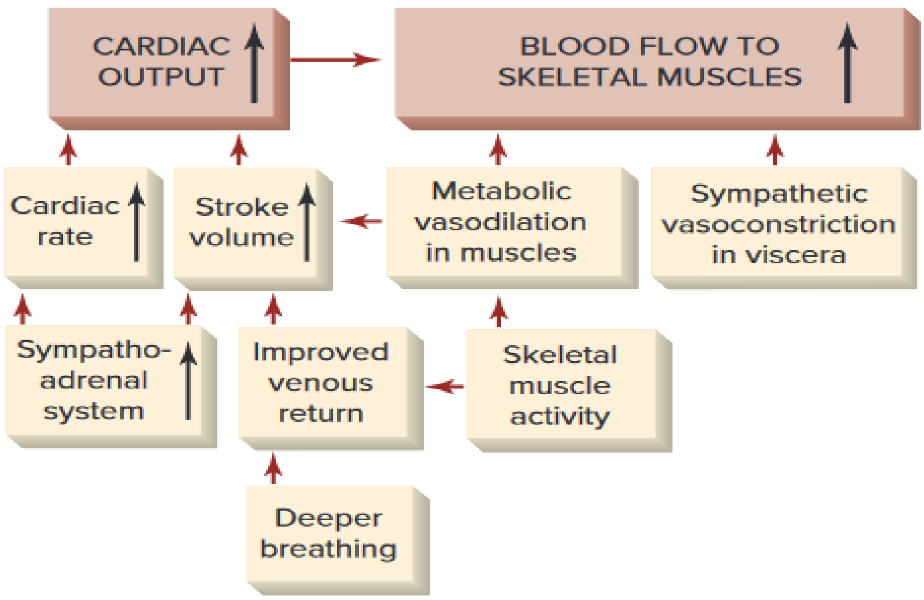

Figure 1: Cardiovascular adaptations in response to exercise training

How does the cardiovascular system respond when an individual first moves from a reclining position proceeding to running phase

- There is a steady increase in heart rate (HR)
- Reduction in stroke volume (SV) while patients change from reclining to erect posture due to pooling of blood in lower limbs.
- To compensate for the reduction in SV, HR increases in order to maintain cardiac output; that is, Q = HR x SV
- The initial increase in HR is due to withdrawal of parasympathetic (vagal) tone& further increases in HR is due to increased sympathetic activation.

Cardiovascular parameter that is practically considered in exercise training are Heart rate (HR), Resting heart rate (RHR) & HRmax

Resting heart rate (RHR)

- Estimated in completely relaxed state
- Pre exercise HR is not a reliable RHR due to anticipatory cardiac response.
- Averages 60 to 80 beats/min in most individuals

HRmax

- Highest HR value achieved in an all - out effort to the point of volitional fatigue during evaluation
- HRmax = 220 − age (SD - 10 beats/min)
- If the patients are on Beta - Blockers we must be careful regarding the estimation of RHR & HRmax.

Pulmonary Adaptations with Training

VENTILATION (Ve):

- Ventilation is the volume of air exchanged per minute. Ve increases with the onset of exercise
- At maximal exercise it increases 15 - 25 fold over resting values
- During mild to moderate exercise Ve increases primarily by increasing Tidal Volume.
- During vigorous activity it increase by increasing the Respiratory rate.
- Maximal values for Tidal volume, ventilatory rate, and ventilation are increased after training.

Advantages of Pulmonary Adaptations

- Decreases breathing frequency - so that air remains in the lungs for a longer time between breaths→ increase in oxygen extraction from inspired air.
- Gas exchange in the alveoli increases so larger oxygen utilization &better CO_2 Elimination occur.
- Minimizes respiratory work at a given exercise intensity
- Frees oxygen for use by the non - respiratory active musculature training.

VO_2max: Maximal Oxygen Consumption (Aerobic Capacity)

- The most important parameter is VO_2max, which is the Measure of Cardiopulmonary fitness.
- It is the amount of oxygen that can be transported in the blood and utilized in the muscles during maximal exercise while breathing air at sea level

Why does exercise training improve $\dot{v}o_2$ max?

It's because **VO_2max =** Maximal cardiac output × (maximal a - vO_2 difference), where exercise training increases the CO & increase in capillary density causing increase in arterio - venous oxygen difference.

Exercise Intensity Calculation

1) If CPET is available – **VO_2 max** method
2) **Heart rate** method along with baseline exercise tests (eg.6MWT)

- Linear relationship between HR and percentage of VO_2max is the reason for using this principle.
- 55% to 75% of VO_2 max approximates 70% to 85% of an individual's HRmax
- So Target HR= 70% to 85% of an individual's HRmax (220 - age) during exercise training.

BORG RATING OF PERCEIVED EXERTION (RPE)

- It's a subjective assessment of how hard individuals feel while they are exercising.
- Helps when HR estimation may not be accurate as in case of patients taking medications.
- The average RPE range associated with Physiologic Adaptation to exercise is 13 to 16.
- So our target is to achieve "somewhat hard" to "hard" on the Borg Scale category while exercising.

How to Progress the Training?

- Always begin with exercise level tolerated by patient without any discomfort then graded increase in duration followed by increasing the intensity.
- High intensity exercise more useful but always go for a conservative approach as it's the safest approach with patients with cardiorespiratory compromise.
- Aggressive progression will lead to increased dropout rates, injuries, discomfort and drop outs.

Responder/ Non Responder

The presence of Muscle - specific creatine kinase gene provides individual differences in responsiveness of VO_2max to endurance training. So that some will respond to training and some don't due to genetic reasons.

Overtraining

It's always a no to overtraining due to increased incidence of:

- Infections
- Persistent muscle soreness
- General malaise and loss of interest in sustaining high level training.

Importance of Flexibility Training

- Pre - stretching a muscle prior to training enhance the force of muscle contraction. But excessive flexibility will lead to injuries.
- Certain degree of tightness might protect against injury by allowing load sharing when joints are stressed
- If patient has hypermobility Stabilization exercises is to be given

Exercises And Meals

Blood flow to the working muscles is reduced after a meal due to redistribution to splanchnic circulation, so it's advised to exercise after 2 - 3 hrs, if patient has consumed heavy meals.

Exercises & Climate

Exercising in a hot environment will lead to dehydration, so Indoors/cooler times of day is preferred for exercise training.

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