Notes on hyerpnea, emphysema, airway resistance, apnea, spirometry, muscle strength, muscle power, and muscle endurance

Manoj Nath, Post Graduate Teacher
Department of Human Physiology, Women's College
Agartala, Tripura (West), India, PIN-799001

Hyperpnea

Hyperpnea or hyperpnoea is increased depth of breathing when required to meet metabolic demand of body tissues, such as during or following exercise, or when the body lacks oxygen (hypoxia), for instance in high altitude or as a result of anemia. Hyperpnea may also occur as a result of sepsis, and is usually a sign of the beginning of refractory sepsis.

In hyperpnea, the increased breathing rate is desirable as it meets the metabolic needs of the body.

Emphysema

Emphysema is a progressive disease caused by damage to portions of the lungs that lead to the damage of air sacs. As a result, air cannot reach the air sacs and patients are chronically short of breath. It is mainly caused by smoking, and less commonly by long-term exposure to air pollution or other lung irritants. In very rare cases, it can be caused by alpha 1-antitrypsin deficiency.

Emphysema is a chronic obstructive pulmonary disease (COPD). It is often caused by exposure to toxic chemicals, including long-term exposure to tobacco smoke. It occurs when the very small air sacs (called the alveoli) at the ends of the airways in the lungs start to break down from many sacs to form much bigger sacs. Emphysema makes it hard for people to blow air out of the lungs because air gets trapped inside the broken alveoli due to the collapse of the walls.

Cause

The biggest known cause or risk factor for emphysema - and for COPD - is smoking. Cigarette smoking is responsible for around 90% of cases of COPD. Other inhaled toxins also lead to emphysema and COPD. In developing countries, smoke from indoor cooking and heating is also an important cause.

The main cause of emphysema is long-term exposure to airborne irritants, including:

- Tobacco smoke
- Marijuana smoke
- Air pollution
- Manufacturing fumes
- Rarely, emphysema is caused by an inherited deficiency of a protein that protects the elastic structures in the lungs. It's called alpha-1-antitrypsin deficiency emphysema.

Symptoms

Two symptoms are the main markers of emphysema.

- Shortness of breath
- Cough.

Shortness of breath is also known as dyspnea and gives the feeling of being unable to catch a breath. This symptom may be present only during physical exertion but as the disease progresses may be present during rest also.

Other symptoms include-

- Frequent lung infections
- Producing a lot of mucus
- Wheezing
- Reduced appetite
- Weight loss
- Fatigue
- Blueness of the lips or fingernail beds (from cyanosis caused by poor respiration)
- Anxiety, depression
- Sleep problems
- Morning headache signals nighttime breathing difficulty (nocturnal hypercapnia or hypoxemia)

Treatment/Remedy

There is no cure for emphysema. Treatment includes stopping smoking and taking medicines ('broncho-dilators' and sometimes corticosteroids). Supplemental oxygen is recommended in those with low oxygen levels at rest. It decreases the risk of heart failure and death, and may improve people's ability to exercise. Oxygen supplementation may improve shortness of breath.

Airway Resistance

Airway resistance is the opposition to flow caused by the forces of friction. It is defined as the ratio of driving pressure to the rate of air flow. Resistance to flow in the airways depends on whether the flow is laminar or turbulent, on the dimensions of the airway, and on the viscosity of the gas.

Airway resistance is the resistance of the respiratory tract to airflow during inspiration and expiration. (Airway resistance can be measured using body plethysmography.)

$$R_{AW} =$$

Where:

$$\Delta P = P_{ATM} - P_A$$

So:

$$R_{AW} = \frac{P_{\mathrm{ATM}}}{}$$

Where:

- R_{AW}= Airway Resistance

- ΔP= Pressure Difference driving airflow
- P_{ATM}= Atmospheric Pressure
- P_A= Alveolar Pressure
- $\dot{V}$= Volumetric Airflow

The most important variable is radius. If the diameter of a tube is doubled, resistance will drop by a factor of sixteen. For turbulent flow, resistance is relatively large. Airway resistance decreases as lung volume increases because the airways distend as the lungs inflate.

Determinants of airway resistance

There are several important determinants of airway resistance including:

- The diameter of the airways
- Whether airflow is laminar or turbulent

Hagen–Poiseuille equation

the Hagen–Poiseuille equation is a physical law that gives the pressure drop in a fluid flowing through a long cylindrical pipe. The assumptions of the equation are that the flow is laminar viscous and incompressible and the flow is through a constant circular cross-section that is substantially longer than its diameter. The equation is also known as the *Hagen–Poiseuille law*, *Poiseuille law* and *Poiseuille equation*.

$$\Delta P = \frac{8}{}$$

Where:

- ΔP= Pressure difference between the ends of the pipe
- l= Length of pipe
- η= the dynamic viscosity
- $\dot{V}$= the volumetric flow rate (Q is usually used in fluid dynamics, however in respiratory physiology it denotes cardiac output)
- r= the radius of the pipe

Apnea

Apnea (or apnoea) is a term for suspension of external breathing. During apnea, there is no movement of the muscles of inhalation and the volume of the lungs initially remains unchanged. Depending on how blocked the airways are, there may or may not be a flow of gas between the lungs and the environment; gas exchange within the lungs and cellular respiration is not affected.

Cause

Apnea can be voluntarily achieved, drug-induced (such as opiate toxicity), mechanically induced (for example, by strangulation or choking), or it can occur as a consequence of neurological disease or trauma. During sleep in patients who are suffering from sleep apnea,

these events can occur up to 20–30 times per hour, every night. Voluntary apnea can be achieved by closing the vocal cords, simultaneously keeping the mouth closed and blocking the nasal vestibule, or constantly activating expiratory muscles.

Complications

Prolonged apnea leads to severe lack of oxygen in the blood circulation. Permanent brain damage can occur after as little as three minutes and death will inevitably ensue after a few more minutes unless ventilation is restored. However, under special circumstances such as hypothermia, hyperbaric oxygenation, apneic oxygenation or extracorporeal membrane oxygenation, much longer periods of apnea may be tolerated without severe consequences.

Spirometry

Spirometry (*measuring of breath*) is the most common of the pulmonary function tests (PFTs), measuring lung function, specifically the amount (volume) and/or speed (flow) of air that can be inhaled and exhaled. Spirometry is an important tool used for generating pneumotachographs, which are helpful in assessing conditions such as asthma, pulmonary fibrosis, cystic fibrosis, and COPD.

Significance

Spirometry is significant for the following reasons:

- to diagnose or manage asthma
- to detect respiratory disease in patients with symptoms of breathlessness, and to distinguish respiratory from cardiac disease as the cause
- to measure bronchial responsiveness in patients suspected of having asthma
- to diagnose and differentiate between obstructive lung disease and restrictive lung disease
- to follow the natural history of disease in respiratory conditions
- to assess of impairment from occupational asthma
- to identify those at risk from pulmonary barotrauma while scuba diving
- to conduct pre-operative risk assessment before anaesthesia or cardiothoracic surgery
- to measure response to treatment of conditions which spirometry detects
- to diagnose the vocal cord dysfunction.

Muscle Strength

- Muscular strength is the ability of a muscle or muscle group to exert force to overcome the most resistance in one effort.
- Strength is defined as the ability of a specific group of muscles to produce maximal force at a specific speed which is typically slow and normally within a single exertion.

Strength can be measured based on the amount of weight lifted. Upper-body and lower-body strength are measured separately. Strength tests include the bench press for upper body, the squat for lower body and the dead lift for lower back and leg assessments. Relative strength is based on a ratio of weight lifted to body weight. For example, if two people lifted the same weight, the person who weighs less has greater relative strength.

Normally when a person is training for strength it requires very heavy resistance, a low number of repetition and a very long rest period. According to the NSCA guideline for strength training the person should do ≥ 85% of your 1 Rep Max, between 2-6 repetition and between 2-6 sets with a work-rest ratio of 1:12-1:20.

Example of Activities that uses A lot of strength Training are Powerlifting, Strong -man compitions etc.

Muscle Power

Power is defined as the amount of work performed per unit of time. Power is an element of skill-related fitness that is needed to excel in athletic performance. Increased strength does not always translate into increased power. For example, a strong upper body lifts a high amount of weight. However a strong upper body does not always have the ability to throw a shot put very far if enough speed cannot be generated.

Muscular Endurance

- Muscular endurance is the ability of a muscle or muscle group to exert force to overcome a resistance many times. Often the resistance is the body itself.
- Muscle endurance is when a group of muscle can generate sub-maximal force by doing either a repeated moment or maintaining a static position over a period of time.

The measurement of muscular endurance is based on the number of repetitions performed. Muscular endurance tests include push-ups, pull-ups and dips for the upper body, and sit-ups for the abdominals.

How to train for Muscular Endurance

Normally to train muscle endurance it requires doing a number of repetition of an exercise or holding a static position for a long time. For example doing pushups or pull ups to failure or holding onto a pull up bar until the muscle are exhausted and he/she can no longer hold on.

Many factors contribute to muscular endurance, including strength, fiber type, training and diet. A larger, stronger muscle can perform the same task under load more times than a weaker muscle. If a person can bench press 300 pounds he/she will be able to perform more repetitions with 100 pounds than if he/she could only bench 200 pounds. A larger muscle also holds more glycogen, the sugar that a person uses for energy, so it will be able to sustain a series of contractions.