Keywords: Ageing/Respiratory system/Respiratory tract infections/

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In this article...

- How age affects the normal functioning of the respiratory system
- Age-related changes to the airways, lungs and respiratory muscles
- Conditions experienced by older people as a result of declining respiratory function

Anatomy and physiology of ageing 2: the respiratory system

Key points

1. An efficient respiratory system is essential for health and longevity, but age brings about changes that reduce its efficiency
2. As the body ages, respiratory muscles lose strength, lung tissues lose elasticity, the alveolar surface area diminishes and lung capacity is reduced
3. As age increases, the respiratory system is less able to expel inhaled irritants and pathogens due to a reduced coughing reflex and a decline in ciliary escalator function
4. Age is a major risk factor for both community- and hospital-acquired respiratory tract infections
5. Older people should be encouraged to take regular exercise and pay close attention to their respiratory health

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Abstract The respiratory system has a key role in gaseous exchange but also helps to regulate blood pH, control blood pressure and provide non-specific immune defence mechanisms. Like all organ systems, it becomes less efficient with age. This second article in our updated series on age-related changes in the main organ systems looks at the respiratory system.

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The respiratory system has numerous functions: in addition to its central role in gaseous exchange, it is involved in regulating blood pH and controlling blood pressure, and has a role in mechanical non-specific immune defences (Marieb and Hoehn, 2015; Montague et al, 2005). This article explores the anatomical and physiological changes that occur in the respiratory system with age.

Every living cell in the body needs oxygen for cellular respiration and generates carbon dioxide as a waste product; an efficient respiratory system is therefore vital for cellular function and general health. Although the respiratory system maintains adequate gaseous exchange and carries out its other functions effectively throughout life in the absence of any pathology, the cumulative effects of ageing mean its efficiency progressively diminishes. However, these effects can be reduced by regular exercise throughout life.

Anatomical changes

Chest wall

In early life, the chest wall is relatively supple. With age there is a gradual increase in rib calcification, particularly in the anterior cartilaginous (costal) areas close to the sternum (Figs 1 and 2) and, to a lesser extent, in the areas where the ribs articulate with the vertebral column. These changes mean the chest wall becomes progressively more rigid (Janssens et al, 1999).

With age, the intervertebral discs gradually become desiccated, less robust and more compressed under the weight of the body. This often results in the characteristic curvature of the thoracic spine seen in many older people. In some – particularly older women with osteoporosis or muscle wastage – this curvature can exceed 50 degrees (hyperkyphosis). Age-related curvature of the thoracic spine causes a narrowing of the spaces between the vertebrae and between the ribs; this progressively reduces the volume of the rib cage (Lowery et al, 2013).

There is also a gradual age-related reduction in respiratory muscle strength, which is thought to be primarily due to a loss of muscle mass in the diaphragm and intercostals. Loss of muscle mass particularly occurs in immobile individuals or in those who lead a sedentary lifestyle, as inactivity promotes muscle wastage and weakness (Nigam et al, 2009).

These changes result in breathing becoming laboured and the coughing reflex less effective which, in turn, increases the risk of respiratory tract infections (Freitas et al, 2010; Kim et al, 2009).

Airway

The respiratory system is extremely vulnerable to infection and damage from pollutants because its warm, moist, 85m² surface area is in continuous contact with the environment (West, 2008). As every inhalation will introduce new infectious agents and irritants, the respiratory tract has an elaborate mechanism, known as the ciliary escalator, to clear particulate debris: mucus coats the inner surface of the bronchial tree and traps inhaled particles such as dust and bacteria. Ciliated cells lift the contaminated mucus away from the lungs and, on arrival in the pharynx (throat), this mucus is swallowed and passes into the acidic, sterilising environment of the stomach (Marieb and Hoehn, 2015). If the ciliary escalator is ineffective, pathogens, mucous and debris are not cleared from the lungs as quickly and the risk of infection increases.

The frequency with which cilia beat decreases with age, slowing the ciliary escalator. Research examining individuals aged 19-81 years has demonstrated a clear age-related decline in the clearance of inhaled particles (Svartengren et al, 2005); this may also be related to the gradual decrease in the number of cilia and ciliated cells in the airway (Levitzky, 1984). As cigarette smoke is toxic to ciliated cells, smoking will further reduce the clearance of particles.

In young people, the airways are extremely sensitive to mechanical stimulation: inhaled debris usually provokes vigorous coughing to dislodge and expel any irritants. In older people, the sensory receptors that monitor the airway appear to become less sensitive, so the coughing reflex may not be triggered. This increases the risk of pathogens and irritants reaching the deep lung tissues and causing RTIs. Even if a coughing reflex is triggered, the reduction in inspiratory and expiratory muscle strength reduces its effectiveness (Freitas et al, 2010).

The airways between the nose and the bronchioles are known as the conduction zone: this is an anatomical dead space – a space where no gas exchange takes place. The cartilaginous rings that hold the upper airways open gradually calcify with age, which increases the diameter of the larger airways, particularly the trachea and bronchi, causing this dead space to grow (Janssens et al, 1999).

Fig 1. **Bones and cartilages of the chest**

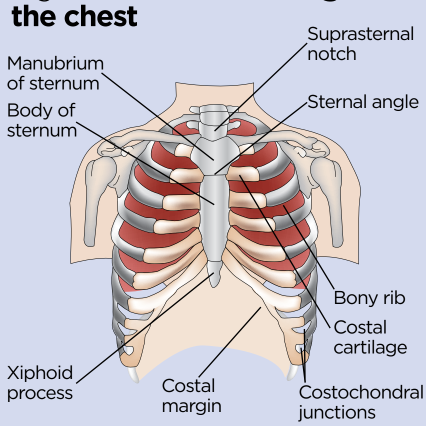
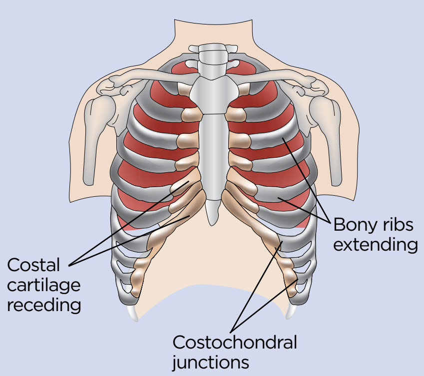


Fig 2. **Increase in rib calcification**



Although the amount of elastin and collagen fibres in the lung tissue remains relatively constant, the lungs themselves gradually lose elasticity and become more dilated. It is thought this is primarily due to changes in the nature of the collagen and elastin fibres, which either become cross-linked or degenerate, progressively reducing the elastic recoil of lung tissue (Levitzky, 1984).

Alveolar changes

As middle age approaches, the loss of elasticity in the lung tissue and airways leads to a progressive increase in the diameter of the respiratory bronchioles and alveolar ducts (tiny tubes leading into the alveoli). After the age of 50, the elastic fibres in the alveolar ducts start to degenerate, leading to alveolar duct dilation (Sharma and Goodwin, 2006). This widens the structure and reduces the depth of the alveoli. Over time, the alveolar walls may begin to disintegrate and the air sacs enlarge, often taking a flattened appearance and reducing the total alveolar surface area.

Healthy alveoli have a resident population of macrophages (cells that trap particulate material that has reached the end of the airways) (Marieb and Hoehn, 2015). Older people have fewer macrophages but more pro-inflammatory neutrophils; their macrophages and neutrophils are more sensitive and so more likely to release granules (mainly enzymes) and highly reactive oxygen molecules (superoxide anions), which leads to low-grade inflammation in the lower respiratory tract. This may contribute to the breakdown of alveolar structure often seen in aged lungs (Sharma and Goodwin, 2006).

People in their 90s have typically lost around 25% of their alveolar surface area. These changes are often exacerbated in smokers (and individuals who inhale other particulate irritants), leading to the severe emphysema characteristic of chronic obstructive pulmonary disease (Verbeken et al, 1992).

The increased production of inflammatory mediators in aged lung tissue may also contribute to the exacerbation of allergic reactions. Indeed older people appear to be at increased risk of multiple allergies (multiple allergy syndrome) and mortality from serious reactions such as allergy-induced asthma (Bom and Pinto, 2009).

Pulmonary circulation

Pressure in the pulmonary artery (wedge pressure) gradually increases with age, even in the absence of pathology. This is primarily due to a loss of arterial elasticity and associated ventricular hypertrophy (see Part 1 of this series).

Functional changes

The structural changes described above lead to changes in lung function. Some of these can be recorded by spirometry and other techniques (Spirduso et al, 1995).

Lung volume

Residual volume (RV) is the air remaining in the lungs after a full, forced expiration. It is normally around 1.2L at age 25 and gradually increases due to loss of lung elasticity. Less-elastic lungs become more distended as they have reduced recoil during expiration; this results in air trapping. A typical 70-year-old's RV will have increased by some 50% to around 1.8L (Lee et al, 2016).

Vital capacity (VC) is the total volume of air that can be exhaled after a full inspiration. In an average man aged 25, this is around 5L, declining to around 3.9L at age 65. In women, it decreases from around 3.5L to around 2.8L (Spirduso et al, 1995). These reductions are primarily due to the gradual increase in chest-wall rigidity and the loss of respiratory muscle strength described above. In the average non-smoker, VC can be expected to decrease by around 200ml per decade (American Lung Association, 2016).

Total lung capacity is the total volume of air in the lungs following a full inspiration. It is around 6L in men and 4.2L in women and does not change significantly throughout life. It has been hypothesised that this is because the reduced lung elasticity is counterbalanced by the increased rigidity of the chest wall (Janssens, 2005).

Tidal volume is the amount of air exchanged during normal breathing. It is typically around 500ml and, in the absence of pathology, does not change significantly with age. However, because of increased chest-wall rigidity and reduction in lung elasticity, a 60-year-old will expend 20% more energy during normal breathing than a 20-year-old (Janssens et al, 1999).

Oxygen saturation

Age-related changes to the respiratory tract ultimately result in a reduced delivery of oxygen to the blood and a decrease in oxygen saturation. Using a pulse oximeter, a reading of 96-98% saturation would be expected at sea level in individuals aged under 70 years; in those aged 70 years or older, 94% is taken as normal (GP Notebook, 2017).

Capacity for exercise

Aerobic capacity diminishes by 6-10% per decade (Kasch et al, 1993): a standard six-minute walk test (which measures the distance that can be walked in six minutes) shows that individuals aged 80 years walk around 200 metres less than those aged 40 years (Janssens, 2005). This occurs primarily due to age-related reduction in cardiovascular function (see Part 1 of this series), but some changes to the respiratory system – increased anatomical dead space, reduced VC – contribute to this decreased capacity for exercise. Conversely, a lack of exercise compounds the reduction in breathing efficiency, as sedentary individuals will lose significantly more respiratory muscle strength and mass (Pereira et al, 2014).

Susceptibility to RTIs

Age is a major risk factor for RTIs. Some reasons for this have already been highlighted:

- Reduced clearance of particulate material and mucus by the ciliary escalator;
- Reduced coughing reflex, increasing the risk of mucus collecting in the airway;
- Reduced elastic recoil of lung tissue;
- Senile emphysema.

Many other factors contribute to this increased risk of RTIs in older people, one of them being aspiration. Around half of all adults aspirate oropharyngeal secretions from the throat into the lower respiratory tract while asleep. In younger people, with efficient ciliary escalators and coughing reflexes, these aspirates are readily cleared, but, in older people, they may remain in the lung tissue, increasing the risk of infection. Aspiration issues are seen in around 71% of patients with community-acquired pneumonia and are common in older patients who have dementia, are recovering from stroke or are being fed via nasogastric tubes (Janssens and Krause, 2004).

Viral and healthcare-associated RTIs

Viral RTIs are more common in winter and older people are at the greatest risk of infection. Older people are also at higher risk of hospital-acquired (nosocomial) pneumonia; the risk increases proportionately with the length of stay. Older patients with pneumonia often do not display characteristic signs and symptoms; many present following a fall or bout of confusion (Janssens and Krause, 2004).

Maintaining a healthy respiratory system

Regular exercise is essential to help maintain a healthy respiratory system. Recent studies indicate that this exercise does not need to be intense. Yoga appears to be effective in improving lung function: in Kadu and Deshpande's (2013) study, middle-aged men who had done six months of yoga had significantly increased VCs and reduced breathing rates compared with those who had not done any yoga.

Since the efficiency of the respiratory system declines and the risk of respiratory tract diseases increases with age, it is important to encourage older patients to pay closer attention to their respiratory health, and to seek advice should they notice any changes in their respiratory function. **NT**

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