MEDICAL SCIENCE

# Impact of aging on respiratory system; literature review article

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## ABSTRACT

Saudi Arabia is undergoing a demographic transition as the proportion of people 60 and older is predicted to rise from 2 million to 10.5 million between 2020 and 2050. Aging affects respiratory system as long as other systems in the body. Aging-related changes to the respiratory system typically include structural alterations to the thoracic cage and lung parenchyma, aberrant lung function test results, ventilation and gas exchange anomalies, lower exercise tolerance, and weaker respiratory muscle strength. Reduced elastic recoil of the thoracic cage and lung parenchyma results in decreased respiratory system compliance, which in turn results in less energy expended by the respiratory system. Age causes a decline in lung function as indicated by 1-second forced expiratory volume and forced vital capacity (FVC), but total lung capacity does not vary. Diffusion capacity also diminishes as a result of the increased residual volume. The alveolar-arterial oxygen differential may rise due to increased physiological dead space and a ventilation/perfusion imbalance. The age-related muscular atrophy is estimated to be responsible for a greater than 20% decline in diaphragm strength. Age does not result in an increase in blood carbon dioxide content or ventilation per minute. Responses to hypercapnia and hypoxia, however, are diminished. Maximum oxygen consumption falls by >1% year, along with exercise capability. As a result of these changes, ageing is accompanied with an increase in respiratory disorders. It is crucial to understand these respiratory system modifications brought on by ageing.

**Keywords:** Respiratory system, aging

## 1. INTRODUCTION

In Saudi Arabia, 4.9% (1.4 million) of the country's population was over 60 in 2012. By 2050, this proportion was expected to rise to up to 21.8% (10 million), according to the same estimate (UNFPA and HAI, 2012). The respiratory system changes as a result of ageing, among other alterations to the human body. However, due to stark interindividual variability, normal variations of such alterations could be difficult to discern from pathological changes

(Häder et al., 2023). In healthy individuals with reserve lung capacity, changes in the respiratory system with ageing do not result in major issues such airway blockage or parenchymal lung disease.

However, the reserve is diminished when the sick person also has underlying lung illness from prior infections or smoking, making lung issues more likely to develop. The most typical changes in the respiratory system brought on by ageing include structural changes in the thoracic cage and lung parenchyma, abnormal outcomes on pulmonary function tests, abnormalities in ventilation and gas exchange, decreased respiratory muscle strength, and reduced exercise capacity.

**Study objective**

The authors of this paper want to outline the physiological changes brought on by ageing, including variations in the dynamics of the respiratory system, irregularities in gas exchange, and modifications in exercise tolerance and respiratory muscle strength.

## 2. METHOD

Until August 27, 2023, we searched Medline, PubMed and Scopus for potentially pertinent papers. The respiratory system, ageing, the cough reflex, exercise, hypoxia, hypercapnia, muscle power, anatomical changes, and lung function were all taken into consideration while selecting articles. Two researchers (Mohammed AA and Mohammed SA), independently read the full-text manuscripts and abstracts and chose the pertinent articles. Consensus meetings were used to settle disagreements. After that information's categorized and divided into 8 sections listed in the results of this literature review study.

## 3. RESULTS

**Effect on lung function**

The results of pulmonary function tests are impacted by alterations in the respiratory system brought on by ageing, such as a decline in compliance and respiratory muscle strength (Hol et al., 2022; Colloca et al., 2010). Individuals' lung function peaks in their early 20s, is sustained for a while, and then naturally declines as they age. In general, it is known that 1-second forced expiratory volume (FEV1) declines up to the age of 25–39 years by roughly 20 mL/year, but declines by 35 mL/year in individuals beyond the age of 65 (Johannessen et al., 2006; Ketata et al., 2012). Age-related declines in forced vital capacity and forced expiratory volume in one second do not follow a linear pattern, and males experience these declines at a higher pace than women.

Residual volume increases and vital capacity decreases with age, but total lung capacity remains stable or slightly declines. A 70-year-old's residual volume rises by roughly 50% and their vital capacity falls by 75% when compared to a 20-year-old. As a result, the ratio of RV/TLC rises with age, and this rise is thought to be caused by decreased thoracic wall compliance and lung elasticity, weaker expiratory muscular strength, and higher closed lung capacity (Hopkins et al., 2023; Roman et al., 2016). The peak expiratory flow rate peaks between the ages of 30 and 35, after which it gradually drops, especially after the age of 45. After age 50, men's PEFR declines at a rate of 4 L/min/year and women's PEFR declines at a rate of 2.5 L/min/year. Based on the flow rate-volume curve, these reductions point to small airway illness (Roman et al., 2016).

A reduction in the diameter of the peripheral airway can be used to explain age-related small changes in airway resistance; however, as people age, the diameter of the central airway increases, offsetting the effects of an increase in peripheral airway resistance, which makes up only 10% of the total airway resistance. Additionally, as people age, their ability to diffuse carbon monoxide (DLCO) diminishes by 0.15 mLCO/min/mmHg/year in women and by 0.15 mLCO/min/mmHg/year in males. According to reports, women have less decline than men, which may be related to estrogen's role in maintaining blood vessel integrity. Even after accounting for the alveolar size, healthy individuals' diffusing capacity fell when compared to those aged 70 years. The alveolar-capillary membrane alterations brought on by ageing may be the root of this reduction in diffusing ability (Garcia et al., 2012).

Physiological dead space rises due to ventilation/perfusion imbalance brought on by ageing. When a person is between 15 and 20 years old, the dead space accounts for roughly 13% of alveolar ventilation, but when they are between 61 and 75 years old, it rises to 32% (Holland et al., 1968). According to a study by the physiological dead space in a young, healthy person was 150 ml, while the physiological dead space in an old, healthy person was reported to be around 235 67.5 ml. This difference represents an increase of more than 50% (Schaeffer et al., 2021). Elderly adults have lower normal arterial oxygen partial pressures than younger people, despite the fact that changes in alveolar arterial oxygen concentrations, or (Aa) DO2, are increasing with age. However, minute ventilation does not decline with ageing, and carbon dioxide exchange is unaffected. As a result, the existence of respiratory acidosis in the elderly should likewise be considered anomalous.

### Respiratory system dynamics and structural changes

The thoracic cage assumes a rounded shape as a consequence of structural alterations that increase the anterior and posterior diameters of the cage. Age-related calcification of the thoracic joint cartilage and spinal scoliosis brought on by osteoporotic alterations generate increased stiffness and decreased compliance of the thoracic wall. The thoracic compliance decreased with age, according to a study that examined the thoracic wall compliance in 61 healthy persons between 24 and 75 years old (MacAskill et al., 2023).

The effort required for breathing increases due to the thorax's reduced compliance, which also results in decreased energy efficiency (Häder et al., 2023). In addition to structural changes in lung parenchyma, other aging-related changes include periphery airway calcification, decreased elasticity due to changes in the elastic fibres of small airways (reduction by approximately 0.1–0.2 cm $H_2O$ each year), reduction in the proportion of lung parenchyma versus the lung volume, and mucous gland hypertrophy (Rossi et al., 1996; De-Man et al., 2023).

### Effect on respiratory muscle power

Ageing generally results in decreased muscle strength, which also affects the respiratory muscles (Gea et al., 2020; Larsson et al., 2019). Multiple metrics, including the maximum trans-diaphragmatic pressure, the maximal voluntary ventilation, and the maximal inspiratory pressure, can be used to assess the strength of the respiratory muscles. Elderly people have been found to have lower levels of all these factors (Adamiak et al., 2002; Bairapareddy et al., 2021). In a study that evaluated the diaphragm's muscle strength, it was discovered that older adults (65 to 75 years old) had a about 25% lower Pdi max than younger adults (19 to 28 years old) (Tolep et al., 1993).

Similar findings were detected in research by Polkey et al., (1997) and regardless of age, the MIP was 30% greater in males than in women. Men aged 65 to 85 had an annual change in $H_2O$ of between 0.8 and 2.7 cm (Polkey et al., 1997). Age-related muscle atrophy and a decline in the fast fibres that generate a higher level of tension are linked to the diminished diaphragm strength. In older people, a decline in diaphragmatic muscular strength causes breathing rate to increase, which wears out the diaphragm and may eventually lead to ventilatory failure.

Age-related respiratory muscle weakness may not be a significant issue in healthy people, but if ventilation requirements are increased as a result of pulmonary disease, it could be a serious issue leading to respiratory failure. At 50 years old or older, the cross-sectional area of the intercostal muscles is marginally reduced, whereas the cross-sectional area of the expiratory muscles is greatly reduced. Age, on the other hand, has no effect on the diaphragm's thickness. However, the decreased compliance in the chest wall causes the curvature to decrease, which lowers Pdi max. Age-related declines in respiratory muscle power have been linked to nutritional status, and BMI has been found to significantly correlate with both the MIP and the maximal expiratory pressure (Pride, 2005).

### Response of aged lung to hypoxia and hypercapnia

The older and younger age groups have the same minute ventilation. Even though the tidal volume decreases with ageing, the minute ventilation is kept up by speeding up breathing. However, in elderly patients, the ventilator response to hypoxemia or an elevated carbon dioxide concentration may be insufficient (Raurich et al., 2009). According to research done by Kronenberg and Drage, (1973) on healthy young and healthy old volunteers, the elderly people had a 50% lower reaction to hypoxia and a 40% lower response to hypercapnia.

Although the exact process is unknown, structural alterations in the lung and thoracic cage as well as chemosensory receptor malfunction may have contributed to these changes (Kronenberg and Drage, 1973). In healthy people older than 60, the ventilation requirements for carbon dioxide production rose with age. This change was thought to be brought on by an imbalance between ventilation and perfusion and an increase in end expiratory-arterial carbon dioxide concentration brought on by ageing (Rastogi et al., 2022).

### Effect on exercise

Depending on the individual's capacity for physical activity, the maximal oxygen consumption ($VO_2max$), a measure of exercise capacity, reaches its greatest level in people between 20 and 30 years old. Thereafter, it declines by about 1% annually. After 20 to 30 years old, $VO_2max$ typically drops at a rate of 32 mL/min/year in men and at a rate of 14 mL/min/year in women (Aghali et al., 2022).

**Effect on cough reflex**

Cough reflex weak with age. This alteration may be due to decreased cough sensation, elevated vagus and occipital nerve activation thresholds, decreased smooth muscle tension, and diminished cognitive function (Canning, 2007; Mai et al., 2020). Additionally, the power of the respiratory muscles declines, making coughing less effective at expelling secretions or foreign objects. Elderly people are more likely to develop aspiratory pneumonia as a result of this weakened cough reflex (Mai et al., 2020). Main findings of selected studies presented in (Table 1).

**Table 1** Characteristics of the study selected

| Study author | Publication year | Journal | Main findings |
|---|---|---|---|
| Hol L et al | 2022 | Aging | On managing the ventilator, age has no bearing. A higher age was linked to more problems, a longer hospital and intensive care unit stay, and a higher fatality rate. |
| Colloca et al | 2010 | Surg Oncol | Heart, lung, and kidney function all progressively deteriorate with aging. Under typical circumstances |
| Johannessen A et al | 2006 | Am J Respir Crit Care Med | By avoiding inaccurately high FEV1% projected with a consequent underestimating of disease severity, post-bronchodilator prediction equations can help with the management of patients with chronic obstructive pulmonary disease. |
| Ketata W et al | 2012 | Rev Pneumol Clin | In older people, ventilation in reaction to exercise, hypoxia, and hypercapnia is reduced. To separate the consequences of ageing from those of diseases, it is crucial to be aware of changes in the respiratory system associated with growing age. |
| Roman et al | 2016 | Eur Respir J | Loss of pulmonary function may cause elderly people who are active to experience ventilatory limitations during exercise, restricting their capacity to continue to reap the health advantages of physical activity into old age. |
| Garcia et al | 2012 | Chest | These research findings emphasise how crucial it is to choose prediction equations compatible with the study individuals' origin and age characteristics. |
| Schaeffer et al | 2021 | Eur Respir Rev | Exercise-induced increases in expiratory volume / carbon dioxide volume are mechanistically related to aging-associated increases in dead space volume and pregnancy-related decreases in the partial pressure of carbon dioxide equilibrium point. |
| MacAskill et al | 2023 | Physiol Rep | Older males may have higher expiratory muscle pressures as a result of compensatory processes intended to counteract rising airway resistance brought on by ageing. |
| Häder et al | 2023 | Aging Dis | Compared to younger people, the aged population is more prone to lung infections and has a higher incidence of serious illness. |
| Rastogi et al | 2022 | J Appl Physiol | Older persons have a higher prevalence of sleep disordered breathing than do younger people. |

## 4. DISCUSSION

The impact of ageing on lung function varies noticeably. Reduced chest wall compliance and more air trapping are both effects of ageing. After age 70, the rate of decline likely accelerates, indicating that the decline in FEV1 with age has a nonlinear phase. Ageing causes an increase in airspace size due to the loss of supporting tissue. Age-related declines in respiratory muscle strength are substantially more pronounced in men than in women. The respiratory system is able to maintain appropriate ventilation and oxygenation throughout the whole life span, despite these alterations. Age-related reductions in the ventilatory response to hypoxia and hypercapnia render the respiratory system more susceptible to ventilatory failure in high demand conditions (such as heart failure, pneumonia, etc.), which could lead to unfavorable outcomes (Sharma and Goodwin, 2006). Additionally, the diminished awareness of bronchial constriction could cause delayed medical care. Older persons who have chronic lower respiratory tract inflammation may be more vulnerable to harmful environmental exposure and experience a faster decrease in lung function.

**Recommendation**

Future research must focus on the clinical implications of "normal" aging-related alterations to the respiratory system as the population of Saudi Arabia ages.

## 5. CONCLUSION

Our review found that age affects lung functions, decreases the compliance and respiratory muscle power, it also results in structural and dynamic changes and decrease the tidal volume, exercise capacity also cough reflex altered with aging.

**Ethical issues**

All Authors stated that there are no ethical issues in the study

**Authors contribution**

Mohammed Ayed Algamdi: Participated in all steps of the research starting from the research idea to writing manuscript and submission; Mohammed Saleh Almulhim, Abdullah Sultan Alangari, Saud Abdullah Alsalem, Hiba abdulkarim Deria, Abdulaziz Fahad Alkharji, Khalid Mefleh Alrasheedi, Abdulkarim Farhan Alanazi, Wael Mohammed Alqahtani, Fahad Mohammed Alsahli: Participated in literature collection and selection writing introduction and discussion.

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**Conflict of interest**

The authors declare that there is no conflict of interest.

**Data and materials availability**

All data sets collected during this study are available upon reasonable request from the corresponding author.

## REFERENCES AND NOTES

1. Adamiak-Kardas M. Pośrednia ocena czynności mieśni oddechowych za pomoca wskaźników maksymalnego ciśnienia wdechowego i wydechowego w jamie ustenej u zdrowych [Indirect evaluation of respiratory muscle strength with the help of markers of maximal inspiratory and expiratory pressure in the mouth of healthy individuals]. Pol Merkur Lekarski 2002; 12(69):178-180.
2. Aghali A, Khalfaoui L, Lagnado AB. Cellular senescence is increased in airway smooth muscle cells of elderly persons with asthma. Am J Physiol Lung Cell Mol Physiol 2022; 323 (5):L558-L568. doi: 10.1152/ajplung.00146.2022
3. Bairapareddy KC, Augustine A, Alaparthi GK, Hegazy F, Shousha TM, Ali SA, Nagaraja R, Chandrasekaran B. Maximal Respiratory Pressures and Maximum Voluntary Ventilation in Young Arabs: Association with Anthropometrics and Physical Activity. J Multidiscip Healthc 2021; 14:2923-2930. doi: 10.2147/JMDH.S333710
4. Canning BJ. Encoding of the cough reflex. Pulm Pharmacol Ther 2007; 20(4):396-401. doi: 10.1016/j.pupt.2006.12.003
5. Colloca G, Santoro M, Gambassi G. Age-related physiologic changes and per ioperative management of elderly patients. Surg Oncol 2010; 19(3):124-130. doi: 10.1016/j.suronc.2009.11.011
6. De-Man R, McDonough JE, Adams TS, Manning EP, Myers G, Vos R, Ceulemans L, Dupont L, Vanaudenaerde BM, Wuyts WA, Rosas IO, Hagood JS, Ambalavanan N, Niklason L, Hansen KC, Yan X, Kaminski N. A Multi-omic Analysis of the Human Lung Reveals Distinct Cell Specific Aging and Senescence Molecular Programs. BioRxiv [Preprint] 2023; 2023.04.19.536722. doi: 10.1101/2023.04.19.536722
7. Formenti P, Umbrello M, Dres M, Chiumello D. Ultrasonographic assessment of parasternal intercostal muscles during mechanical ventilation. Ann Intensive Care 2020; 10(1):120. doi: 10.1186/s13613-020-00735-y

8. Garcia RF, Dorgham A, Galera R. Prediction equations for single-breath diffusing capacity in subjects aged 65 to 85 years. Chest 2012; 142(1):175-184. doi: 10.1378/chest.11-2021
9. Gea J, Ausín P, Martínez-Llorens JM, Barreiro E. Respiratory muscle senescence in ageing and chronic lung diseases. Eur Respir Rev 2020; 29(157):200087. doi: 10.1183/16000617.0087-2020
10. Häder A, Köse-Vogel N, Schulz L. Respiratory Infections in the Aging Lung: Implications for Diagnosis, Therapy, and Prevention. Aging Dis 2023; 14(4):1091-1104. doi: 10.14336/AD.2023.0329
11. Hol L, Van-Oosten P, Nijbroek S, Tsonas A, Botta M, Neto AS, Paulus F, Schultz M; PRoVENT–COVID; Collaborative group. The effect of age on ventilation management and clinical outcomes in critically ill COVID-19 patients--insights from the PRoVENT-COVID study. Aging (Albany NY) 2022; 14(3):1087-1109. doi: 10.18632/aging.203863
12. Holland J, Milic-Emili J, Macklem PT, Bates DV. Regional distribution of pulmonary ventilation and perfusion in elderly subjects. J Clin Invest 1968; 47(1):81-92. doi: 10.1172/JCI105717
13. Hopkins E, Sharma S. Physiology, Functional Residual Capacity. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023.
14. Johannessen A, Lehmann S, Omenaas ER, Eide GE, Bakke PS, Gulsvik A. Post-bronchodilator spirometry reference values in adults and implications for disease management. Am J Respir Crit Care Med 2006; 173(12):1316-1325. doi: 10.1164/rccm.200601-023OC
15. Ketata W, Rekik WK, Ayadi H, Kammoun S. Vieillissement de l'appareil respiratoire: modifications anatomiques et conséquences physiologiques [Aging of the respiratory system: anatomical changes and physiological consequences]. Rev Pneumol Clin 2012; 68(5):282-289. doi: 10.1016/j.pneumo.2012.06.003
16. Kronenberg RS, Drage CW. Attenuation of the ventilatory and heart rate responses to hypoxia and hypercapnia with aging in normal men. J Clin Invest 1973; 52(8):1812-1819. doi: 10.1172/JCI107363
17. Larsson L, Degens H, Li M. Sarcopenia: Aging-Related Loss of Muscle Mass and Function. Physiol Rev 2019; 99(1):427-511. doi: 10.1152/physrev.00061.2017
18. MacAskill W, Hoffman B, Johnson MA. The effects of age on dyspnea and respiratory mechanical and neural responses to exercise in healthy men. Physiol Rep 2023; 11(16):e15794. doi: 10.14814/phy2.15794
19. Mai Y, Fang L, Zhong S, de-Silva SDSH, Chen R, Lai K. Methods for assessing cough sensitivity. J Thorac Dis 2020; 12(9):5224-5237. doi: 10.21037/jtd-2020-icc-005
20. Polkey MI, Harris ML, Hughes PD. The contractile properties of the elderly human diaphragm. Am J Respir Crit Care Med 1997; 155(5):1560-1564. doi: 10.1164/ajrccm.155.5.9154857
21. Pride NB. Ageing and changes in lung mechanics. Eur Respir J 2005; 26(4):563-565. doi: 10.1183/09031936.05.00079805
22. Rastogi R, Morgan BJ, Badr MS, Chowdhuri S. Hypercapnia-induced vasodilation in the cerebral circulation is reduced in older adults with sleep-disordered breathing. J Appl Physiol (1985) 2022; 132(1):14-23. doi: 10.1152/japplphysiol.00347.2021
23. Raurich JM, Rialp G, Ibáñez J, Ayestarán I, Llompart-Pou JA, Togores B. Hypercapnia test and weaning outcome from mechanical ventilation in COPD patients. Anaesth Intensive Care 2009; 37(5):726-732. doi: 10.1177/0310057X0903700507
24. Roman MA, Rossiter HB, Casaburi R. Exercise, ageing and the lung. Eur Respir J 2016; 48(5):1471-1486. doi: 10.1183/13993003.00347-2016
25. Rossi A, Ganassini A, Tantucci C, Grassi V. Aging and the respiratory system. Aging (Milano) 1996; 8(3):143-161. doi: 10.1007/BF03339671
26. Schaeffer MR, Guenette JA, Jensen D. Impact of ageing and pregnancy on the minute ventilation/carbon dioxide production response to exercise. Eur Respir Rev 2021; 30 (161):200225. doi: 10.1183/16000617.0225-2020
27. Sharma G, Goodwin J. Effect of aging on respiratory system physiology and immunology. Clin Interv Aging 2006; 1(3):253-60. doi: 10.2147/ciia.2006.1.3.253
28. Tolep K, Kelsen SG. Effect of aging on respiratory skeletal muscles. Clin Chest Med 1993; 14(3):363-378.
29. UNFPA and HAI. Ageing in the twenty-first century: a celebration and a challenge. London and New York: HAI and UNFPA 2012.