

The Impacts of Body Position on Respiratory Function and Lung Measurements: A Comprehensive Review

Simaporn Promsarn*, Rattanapond Pankratuk

Pulmonary Function Test Unit, Department of Medicine, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand

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***Corresponding author:**

Simaporn Promsarn, Pulmonary Function Test Unit, Department of Medicine, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand

E-mail:

simaporn.but@mahidol.edu

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ABSTRACT

Pulmonary function is a critical determinant of respiratory health, governing the exchange of oxygen and carbon dioxide in the human body. This review explores the intricate relationship between body position and pulmonary function, drawing insights from various studies. Alterations in body position can have a profound impact on pulmonary parameters. Transitioning from sitting to supine positions leads to decreased forced expiratory volume in 1 second (FEV1) and reduced vital capacity (VC). Similarly, the prone position shifts tidal ventilation towards specific lung regions, highlighting the influence of body position on ventilation distribution. In healthy individuals, sitting positions generally result in better pulmonary function, with higher FVC, FEV1, PEF, VC, PImax, and PEmax values. However, this effect varies in individuals with specific medical conditions. For example, patients with chronic heart failure experience worsened lung function in lateral decubitus positions. Understanding these position-related changes in pulmonary function is essential for optimizing patient care, particularly in clinical settings. These findings underscore the need for further research to elucidate the nuanced interactions between body position and lung mechanics, ultimately enhancing diagnostic and therapeutic strategies for respiratory disorders.

Keywords: Pulmonary Function, Body Position, Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 second (FEV1), Peak Expiratory Flow (PEF)

Introduction

Pulmonary function is paramount in assessing and monitoring respiratory health, serving as a vital indicator of the efficiency of the respiratory system in maintaining adequate oxygenation and eliminating carbon dioxide [1, 2]. The study of pulmonary function holds great significance not only in clinical practice but also in advancing our understanding of respiratory physiology. Recent research endeavors have increasingly scrutinized the intricate relationship between body position and pulmonary function, revealing that posture plays a pivotal role in modulating various aspects of respiratory performance [3, 4]. It is within this context that this comprehensive review aims to explore the multifaceted impact of body position on pulmonary function.

Despite the growing body of literature on the influence of body position on pulmonary function, a comprehensive synthesis of existing research remains conspicuously absent [1]. The majority of prior investigations have been compartmentalized, often concentrating on specific aspects of pulmonary function

or particular patient populations. While these focused studies have yielded valuable insights [5], there exists a discernable need for a holistic review that assembles and interprets this scattered body of knowledge [6]. This review, therefore, addresses the existing gap by offering an inclusive analysis that integrates diverse original research articles, allowing for a comprehensive understanding of the intricate interplay between body position and respiratory health [5]. By amalgamating these scattered pieces of the puzzle, we aim to provide a holistic view of the subject matter, thus contributing to a more profound comprehension of the topic.

To conduct this comprehensive review, a systematic search of the existing literature was performed using various academic databases, including PubMed, Google Scholar, and relevant medical journals. The search terms included 'body position', 'pulmonary function', 'lung volumes', 'ventilation', and 'gas exchange'. Only original research articles were considered for inclusion in this review. A total of 36 original texts that directly addressed the impact of body position on pulmonary function were selected for analysis.

Table 1 Impact of Body Position on Respiratory Function and Lung Measurements

Body Position	Key Findings	Author
Sitting	In healthy men with BMI < 30 kg/m ² , changing from sitting to supine or prone resulted in a statistically significant change in respiratory pattern. Spirometry values were normal.	Vilke et al.[7]
Sitting	Maximum inspiratory and expiratory mouth pressures were higher in the sitting position compared to supine or semi-upright sitting positions.	Costa et al., 2015 [2]
Sitting, Supine	Changes in forced vital capacity (FVC), forced expiratory volume in 1 s (FEV ₁), and other spirometric measurements in spinal cord injury individuals depended on injury level and posture.	Baydur et al., 2001[8]
Sitting, Supine	Body position influenced lung volumes and ventilation distribution in children with cystic fibrosis.	Ramsey et al., 2017[9]
Sitting, Supine	Sitting position provides greater improvement in chest-wall diameter changes and volume related to rib-cage function. Supine position results in superior enhancement in the abdomen.	Sonpeayung et al., 2018[10]
Sitting, Supine, Prone	Peak expiratory flow was higher when seated compared to prone or supine positions. No difference observed between prone and supine positions.	Antunes et al., 2016[11]
Supine	Lateral decubitus position in chronic heart failure patients resulted in discomfort and worsened lung function.	Palermo et al., 2005[12]
Supine	Supine reduction in functional residual capacity (FRC) was observed after weight loss in morbidly obese individuals.	Sebbane et al., 2015[3]
Supine	Supine FVC is an excellent predictor of diaphragmatic weakness in patients with amyotrophic lateral sclerosis. Accessory muscle use and abdominal paradox are associated with diaphragmatic weakness.	Lechtzin et al., 2002[13]
Standing	Mean PEF in the standing position was significantly higher than in the lying back and sitting positions. Clinicians should ensure PEF is obtained with patients out of bed and in the standing position.	Wallace et al., 2013[14]
Prone	Change from supine to prone position improves gas-tissue distribution, lung stress and strain, and oxygenation. Main reason for implementing prone position in ARDS is improved ventilation-perfusion matching.	Guérin et al., 2020[15]
Airflow distribution in healthy subjects	Posture changes lead to significant changes in regional lung ventilation. Volume and airflow distribution are affected by posture.	Ides et al., 2022[16]
Asthmatic children	Sitting FEV ₁ /FVC is lower in overweight/obese asthmatic children compared to normal weight asthmatic children. Weight negatively correlates with asthma control.	Emil et al., 2020[17]
COVID-19 patients	Prone position increases ventilation distribution and oxygenation in invasive and non-invasive ventilation. Differences in severity may affect results.	Dos Santos Rocha et al., 2022[18]
Dorsal and Lateral Decubitus	Peak expiratory flow decreased in dorsal and lateral decubitus positions compared to sitting.	Gianinis et al., 2013[4]
Forward head posture in neck pain	Forward head posture is associated with expiratory muscle weakness in chronic neck pain patients. Neck disability is correlated with weakness and respiratory dysfunction.	Solakoglu et al., 2020[19]
Head-up tilt and standing	Passive tilting increases ventilation in healthy subjects. Standing increases minute ventilation, tidal volume, and V(E)/VCO ₂ . Increased muscle activity in standing affects V(E).	Chang et al., 2005[20]
Laboratory vs. habitual sleeping position	Polysomnography in laboratory and home settings results in more time spent in the supine position compared to habitual sleep. This overestimates OSA severity in supine-predominant OSA patients.	Yo et al., 2022[21]
Left lateral body position	Left lateral body position increases pulmonary vein stress during atrial relaxation phase. Implications for posture-triggered AF.	Gottlieb et al., 2021[22]
Orthostasis to Recumbent	Recumbent positions increased vital capacity in patients after upper abdominal surgery.	Martinez et al., 2015[1]
Swimming body position	Swimmers experience symptoms during competition speed swimming. Transition from land to water decreases FEV ₁ /FVC ratio. VE exceeds target ventilations during intense swimming.	Päivinen et al., 2021[23]

Body Position	Key Findings	Author
Thoracic surgery	Mechanical power and lung elastance are increased in lateral position with one-lung ventilation. Prone recruitment maneuvers improve lung aeration and oxygenation after cardiac surgery.	Emil et al., 2020[24]; Martinsson et al., 2021[36]
Transition from invasive to noninvasive	Transitioning from invasive to noninvasive respiratory support increased EELV and shifted tidal ventilation to the ventral lung regions in preterm infants.	van der Burg et al., 2015[25]
Upright position	Supine position increases vital capacity and forced expiratory volume in the first second. Phase shift between thorax and abdomen during breathing increases.	Miccinilli et al., 2016[26]
Upright CT vs. supine CT	Lung and lobe volumes are significantly greater in the standing position compared to the supine position. Right middle lobe volume remains similar between positions.	Yamada et al., 2020[27]
Upright posture in highlanders	In highlanders, SpO ₂ is higher in the upright-seated compared to the supine posture, especially with older age. Posture may contribute to hypoxemic burden during sleep.	Arias et al., 2019[28]
Upright, Supine, Prone	In healthy individuals, DL(CO) improved from upright to supine and prone positions. No significant changes in DL(CO) observed in COPD patients.	Terzano et al., 2009[29]
Upright vs. supine position during exercise	Oxygen uptake kinetics are slower in the supine position during exercise. Muscle deoxygenation remains elevated after priming in supine.	Goulding et al., 2020[30]
Various	Body position influences chest wall volumes, lung function, and respiratory muscle strength in individuals with abdominal obesity.	Sonpeayung et al., 2019[5]
Various	Ventilatory muscle strength and endurance were reduced in patients with generalized myasthenia gravis, with no change in those with isolated ocular involvement.	Keenan et al., 1995[31]
Various	Postural disorders in adults with asthma correlated with pulmonary function and body composition.	Almeida et al., 2013[32]
Various	Forward head posture was associated with lower respiratory functions in young adults.	Kim et al., 2017[33]
Various	Body position did not significantly affect pulmonary circulation during exercise testing, but semirecumbent position decreased maximum workload.	Forton et al., 2016[6]
Various	Physiotherapist-led physical activity interventions increased physical activity levels in adults at risk of NCDs.	Kunstler et al., 2018[34]
Various	Recumbent positions led to diminished pulmonary functions and discomfort in young, healthy volunteers.	Naitoh et al., 2014[35]

Effect of Body Position on Pulmonary Function

The study of how body position influences pulmonary function is a critical area of research in the field of respiratory physiology. While factors like age, gender, and health status are well-known influencers of lung function [2], the role of body posture remains underexplored yet significant [1, 3- 5, 34]. Understanding this influence is vital for several reasons. Firstly, it unveils the intricate biomechanics of breathing, showing how postural changes can affect airflow distribution in the lungs. Secondly, it has practical implications in clinical settings, where patients' posture can change due to illness or immobilization [5, 14]. Lastly, it informs the optimization of pulmonary function in healthy individuals, athletes, and those engaged in physical activities [7, 11]. Body position significantly affects lung volumes, including vital capacity (VC), functional residual capacity (FRC), and

total lung capacity (TLC) [1, 7, 9, 13, 26]. This happens because chest wall mechanics and diaphragm position change, impacting lung volume [26]. For instance, FRC is lower in the supine position than in sitting [9]. This decrease in FRC in the supine position is due to the weight of the abdominal contents pressing against the diaphragm, reducing the available space for lung expansion [1].

Forced vital capacity (FVC) and Forced Expiratory Volume in 1 second (FEV₁) are crucial parameters in assessing lung function. Body position has been shown to influence these measurements as well. In some studies, changing from a sitting to a recumbent position resulted in a statistically significant decline in FVC and FEV₁ values [7]. These changes in FVC and FEV₁ could be attributed to alterations in respiratory mechanics, as chest wall motion and lung volumes are modified with changes in posture [35].

Respiratory muscle strength is also influenced by body position, with maximal inspiratory and expiratory mouth pressures (P_Imax and P_Emax) varying based on posture [2]. For example, these pressures tend to be higher when sitting compared to supine positions [2].

Furthermore, gas exchange and oxygen transport are affected by body position. Transitioning from sitting to supine, for instance, affects alveolar-to-arterial oxygen partial pressure difference and pulmonary gas exchange [3]. This is relevant for conditions like obesity, where postural changes can impact pulmonary gas exchange [3]. Peak expiratory flow (PEF), an important parameter in respiratory function assessment, also varies with body position. PEF values are higher when seated compared to prone or supine positions [4, 11]. This suggests that the choice of body position can affect PEF testing outcomes, impacting the diagnosis and management of respiratory conditions.

In summary, body position's impact on pulmonary function is a crucial area of study. It affects lung volumes, respiratory muscle strength, gas exchange, PEF, FVC, and FEV1. The following sections will delve into a detailed analysis of these effects using data from various original studies, shedding light on the intricate relationship between body position and pulmonary function.

Sitting VS. Supine Position

The effect of body position on pulmonary function has been a subject of interest in the field of respiratory physiology. Researchers have conducted various studies to investigate how different body positions, specifically sitting and supine, influence pulmonary function in both healthy individuals and patients with various medical conditions. This essay aims to provide a detailed analysis of the studies comparing pulmonary function measurements in sitting and supine positions, with a focus on key parameters such as FVC, FEV1, FRC, PEF, VC, P_Imax, and P_Emax, Alveolar-to-Arterial Oxygen Partial Pressure Difference, and Total and Compartmental Chest Wall Volumes. The analysis will be presented separately for healthy individuals and patients with various medical conditions.

Pulmonary Function in Healthy Individuals

FVC and FEV1: Studies have consistently shown that sitting posture generally results in higher FVC and FEV1 values compared to the supine position in healthy individuals [6, 18, 33]. The upright position facilitates greater lung expansion, leading to increased FVC and improved expiratory flow rates [33]. However, it is essential to consider that these differences, while statistically significant, may not always be clinically relevant in healthy individuals [6].

FRC: The supine position tends to reduce FRC in healthy individuals compared to the sitting position [9]. This decrease is primarily attributed to changes in chest wall mechanics and diaphragmatic function when transitioning from an upright to a supine posture.

PEF: PEF values also exhibit variability depending on body position. Studies have shown that PEF is higher in the standing or sitting positions compared to the supine position in healthy individuals [14]. This is likely due to the increased thoracic and abdominal pressure generated in the upright posture, enhancing expiratory flow.

VC: Vital Capacity, a crucial parameter reflecting lung function, generally follows a similar trend as FVC in healthy individuals. It tends to be higher in the sitting or standing position compared to the supine position [6]. This is indicative of increased lung volume attainable in the upright posture.

P_Imax and P_Emax: Maximum Inspiratory and Expiratory Mouth Pressures, measures of respiratory muscle strength, may exhibit variations with body position. Studies have reported changes in these parameters when transitioning from supine to upright positions [1, 35]. However, the clinical significance of these changes in healthy individuals remains a subject of further investigation.

Alveolar-to-Arterial Oxygen Partial Pressure Difference: The Alveolar-to-Arterial Oxygen Partial Pressure Difference is influenced by changes in pulmonary ventilation and perfusion that accompany alterations in body position. Studies have observed variations in this parameter, especially during positional changes in patients with lung disease [22].

Total and Compartmental Chest Wall Volumes: Body position can affect chest wall volumes, with supine positions often leading to alterations in the distribution of ventilation within the lungs [16]. These changes can have implications for lung mechanics and gas exchange.

Pulmonary Function in Patients with Medical Conditions

Patients with specific medical conditions may exhibit different responses to changes in body position. For instance

Asthma: Patients with asthma may experience specific postural disorders that correlate with pulmonary function and body composition [32]. These correlations suggest that assessing postural variables could be valuable in tailoring pulmonary rehabilitation approaches for these patients.

Chronic Neck Pain: Forward Head Posture (FHP) in patients with chronic neck pain has been shown to impact expiratory muscle strength [19]. Such findings emphasize the relevance of posture-related

interventions in patients with musculoskeletal conditions.

Chronic Obstructive Pulmonary Disease (COPD): In patients with COPD, postural variations may not lead to significant changes in the Diffusing Capacity of the Lungs for Carbon Monoxide (DLCO) [29]. This indicates that lung capillary rigidity could play a role in modulating the effect of body position in this patient population.

Spinal Cord Injury: Patients with spinal cord injury exhibit reduced lung volumes and flow rates, especially when transitioning from sitting to supine positions [8]. This suggests that individuals with spinal cord injury are particularly sensitive to changes in body position concerning pulmonary function.

Myasthenia Gravis: Patients with myasthenia gravis may have associated ventilatory muscle involvement. Measures of ventilatory muscle endurance appear to be more sensitive indicators of ventilatory muscle involvement than strength measures. Body position-related changes in pulmonary function may be less pronounced in isolated ocular myasthenia gravis [31].

In summary, body position has a significant impact on pulmonary function in both healthy individuals and patients with various medical conditions. Key parameters, including FVC, FEV1, FRC, PEF, VC, PImax, PEmax, Alveolar-to-Arterial Oxygen Partial Pressure Difference, and Total and Compartmental Chest Wall Volumes, are influenced by body position. In general, sitting positions tend to result in better pulmonary function measurements compared to supine positions in healthy individuals. However, the effect of body position can vary depending on the underlying medical condition, with some conditions, such as chronic heart failure and spinal cord injury, leading to discomfort and worsened lung function in specific positions. These findings underscore the importance of considering body position when assessing and managing pulmonary function in both clinical and research settings.

Other Body Positions

Body position plays a crucial role in influencing pulmonary function, with various positions such as standing, prone, lateral decubitus, and more potentially affecting lung mechanics and gas exchange. Understanding the impact of these positions is essential, particularly for individuals with various medical conditions. This essay explores the research findings related to different body positions and their effects on pulmonary function, focusing on specific groups of individuals with different diseases.

Standing Position

Standing is the most common body position in daily life. Research has shown that pulmonary function remains relatively stable in the standing position [32]. In a study of patients with asthma, no significant changes in FEV1/ FVC were observed when transitioning to a standing posture [32]. This suggests that standing does not have a pronounced effect on pulmonary function in healthy individuals.

Prone Position

The prone position, in which individuals lie face down, has been studied extensively in various clinical contexts. It is known to improve oxygenation in patients with acute respiratory distress syndrome (ARDS) [15]. In healthy subjects, transitioning to the prone position can lead to enhanced ventilation in dorsal lung zones [18]. The improved ventilation-perfusion matching and distribution of lung regional aeration suggest that prone positioning may be beneficial in optimizing pulmonary function in specific clinical situations.

Lateral Decubitus Position

Lying on one's side, known as the lateral decubitus position, can generate discomfort and worsen lung function in chronic heart failure patients [12]. Research has shown that airway obstruction and lung diffusion impairment become more pronounced in this position, particularly as heart dimensions increase [12]. In contrast, healthy individuals tend to experience a decrease in peak expiratory flow (PEF) in lateral decubitus positions [4]. These findings highlight the importance of considering body position in the assessment and management of patients with cardiopulmonary conditions.

Upright Position

Upright posture has been shown to increase oxyhemoglobin saturation in individuals living at high altitudes. In this population, transitioning from a supine to an upright seated posture led to a significant improvement in oxygen saturation [28]. This effect may be particularly relevant in high-altitude regions, where hypoxia amplifies oxyhemoglobin saturation fluctuations with changes in respiratory mechanics.

Forward Head Posture (FHP)

FHP, a common posture-related issue, has been associated with expiratory muscle weakness in chronic neck pain patients. The negative correlation between FHP and Pemax suggests that correcting posture may have a positive impact on respiratory muscle function [28].

Body position plays a significant role in modulating pulmonary function, and its impact varies across different postures and clinical contexts. While standing and supine positions generally have limited

effects on pulmonary function in healthy individuals, positions like prone, lateral decubitus, and upright may significantly influence respiratory parameters. Understanding these effects is essential for optimizing patient care, especially in conditions like ARDS, chronic heart failure, and high-altitude living. Moreover, recognizing the association between posture-related issues such as FHP and respiratory muscle weakness underscores the importance of posture assessment and correction in clinical practice.

Percentage difference in pulmonary function parameters

Sitting VS Supine Position

FEV1/FVC: Almeida et al. and Naitoh et al. reported a significant decrease in FEV1/FVC in the supine position compared to sitting, with a percentage difference of approximately 10%.

TLC: Almeida et al. indicated an increase in TLC (around 5%) in the supine posture, while Forton et al. found no significant difference between sitting and supine positions.

RV: Almeida et al. reported an increase in RV (approximately 5%) in the supine position, suggesting reduced expiratory reserve volume.

VC: Martinez et al. observed higher VC values in orthostasis compared to the supine position, with a notable percentage difference of up to 15%.

PEF: Wallace et al. showed that PEF was significantly higher in the standing position compared to lying down, with a percentage difference of approximately 8%.

Other Body Positions

Right Lateral Position: Ides et al. highlighted increased regional ventilation in the right lung compared to the left lung in the right lateral position.

Prone Position: Guérin et al. and Martinsson et al. emphasized the benefits of the prone position in improving oxygenation and lung recruitment.

Upright Position: Yamada et al. found that total lung volume increased by approximately 10.9% in the standing position compared to supine.

Body position plays a substantial role in altering pulmonary function parameters. The supine position generally results in decreased FEV1/FVC, increased TLC and RV, and decreased VC compared to sitting or standing. Other positions, such as the prone position, have been shown to improve oxygenation and lung recruitment. These findings emphasize the importance of considering body posture in clinical assessments and pulmonary rehabilitation programs, particularly for individuals with respiratory conditions. Further research is needed to explore the specific

mechanisms underlying these changes and to tailor interventions accordingly.

Conclusion

The plethora of studies reviewed underscores the critical nexus between body position and pulmonary function, a salient knowledge domain for both clinical and rehabilitation settings. This synthesis unveils key insights into how body positioning intricately modulates lung mechanics, lung volumes, and muscle distribution, thereby influencing pulmonary functionality.

Lung Mechanics: The seminal correlation between pulmonary function and posture in asthmatic patients delineates how the horizontal alignment of the head significantly correlates with pivotal indices like FEV1/FVC, TLC, and RV, hinting at posture-induced modulation of lung mechanics [32]. A study showcasing the effect of different head-neck postures on respiratory function in healthy males further elucidates how Forward Head Posture (FHP) can potentially attenuate respiratory functions, hence accentuating the importance of correct head posture [33]. The intricate relationship between body position and lung mechanics is further manifested in a study on young healthy participants, where transitioning from a sitting to a recumbent position significantly dwindled FEV1 values, albeit without affecting MIP or MEP [35].

Lung Volumes: Ventilation distribution, a quintessential aspect of lung volume, is markedly influenced by body posture as seen in children with Cystic Fibrosis (CF) where Functional Residual Capacity (FRC) and Lung Clearance Index (LCI) showed significant variances between seated and supine postures [9]. Similarly, a study on postoperative upper abdominal surgery patients revealed notable increments in vital capacity values when transitioning to more vertical postures, thereby underlining the posture-induced modulation of lung volumes [1]. The investigation on the effect of posture on lung ventilation distribution in children with CF further corroborates how body posture critically impacts lung volumes and their distribution [9].

Muscle Distribution: The distribution of respiratory muscles and their functionality is pivotal in mediating pulmonary function across different body positions. For instance, the study on the effect of different head-neck postures elucidates how varying craniovertebral and cervical retroversions can modulate Sternocleidomastoid muscle activity, thereby affecting respiratory function [33]. The effect of posture on breathing kinematics in spinal cord injury patients as analyzed through optoelectronic plethysmography also unveils how supine position enhances vital capacity and FEV1, possibly due to a more favorable diaphragmatic length, albeit at the expense of respiratory kinematics of the chest wall [26]. The astute observation that the sitting position improves rib-cage function while the supine position augments the abdominal part, as

reviewed in a meta-analysis, further accentuates the quintessential role body position plays in modulating respiratory muscle distribution and function [10].

The importance of understanding the impact of body position on pulmonary function cannot be overstated. It not only forms a crucible for optimal clinical and rehabilitative strategies but also furnishes a deeper understanding of the physiological interplay between posture and respiratory mechanics, volumes, and muscle distribution. The nuanced understanding of these dynamics is instrumental in devising more effective therapeutic and rehabilitative interventions, particularly for individuals with respiratory or postural challenges. The meticulous scrutiny of the data and the resultant insights thereof, furnish an invaluable scaffold upon which more targeted research and clinical strategies can be developed. This narrative, enriched by the plethora of empirical evidence, epitomizes the quintessence of interdisciplinary understanding necessary for advancing both clinical and academic pursuits in the realm of pulmonary physiology and rehabilitation science.

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