

Respiratory System and Stretching

Mustafa Burak CAĞDANLIOĞLU

Kemal Serhadlı Police Vocational Training Center Directorate

To Cite This Chapter:

Cagdanlioglu, M. B. (2025). Respiratory system and stretching. In F. Alincak (Ed.), *Current studies in sports science* (pp. 60–68). ISRES Publishing.

Respiratory System

This remarkable system begins at the mouth and nose, proceeds through the conducting airways, and reaches numerous air sacs surrounded by a capillary network. Through synchronized work with the muscles, it facilitates the processes of inspiration and expiration. The respiratory system has the ability to supply the body with the oxygen (O) it requires and to remove carbon dioxide (CO) both at rest and during intense exercise. The work of breathing refers to the effort needed to overcome the forces encountered during inspiration, such as lung and chest wall elasticity and airway resistance. While expiration is generally a passive process, inspiration requires active muscular effort (Gürsoy, 2004). All living cells depend on oxygen to sustain life and maintain healthy function. The respiratory system satisfies this essential need by enabling efficient gas exchange. It is an undeniable determinant of the body's overall performance capacity in all energy-requiring activities. Efficient functioning of the respiratory system enhances an individual's vitality and overall effectiveness in daily life (Erkal, 2000).

Respiratory Organs and Their Functions

The organs of the respiratory system include the mouth, trachea, nasal cavity, larynx, pharynx, right (three-lobed) and left (two-lobed) lungs, bronchi, alveoli, and bronchioles. Each breath of air travels through this pathway from start to finish. Anatomically, the lungs are not directly attached to the chest wall but rest upon a thin layer of serous fluid secreted and maintained by two membranes collectively known as the pleura. The space between them is the pleural cavity. The visceral pleura adheres to the lungs, while the parietal pleura attaches to the thoracic wall and diaphragm. Under certain conditions, the pressure within the pleural cavity (intrapleural pressure) may fall below atmospheric pressure, increasing the risk of lung collapse (atelectasis). The essential function of the pleura is to prevent such collapse. Air enters the respiratory tract through the nose, the mouth, or both. During quiet breathing, nasal inhalation predominates because it warms and humidifies the air. The nasal passages not only condition the air but also filter out dust and other debris through the nasal mucosa. However, during strenuous exercise—when a greater volume of air is required—oral breathing becomes more efficient (Ehrman, Kerrigan, & Keteyian, 2018).

Respiratory Muscles and Breathing

Muscle tissue in the body varies in form and function. Structurally, respiratory muscles resemble skeletal muscles; however, their specialized roles distinguish them functionally (Eston & Reilly, 2001). While skeletal muscles primarily generate movement, respiratory muscles are designed to overcome resistance and elastic loads within the thoracic cavity (Edwards & Faulkner, 1995). Inspiration begins with contraction of the dome-shaped diaphragm, which separates the thoracic and abdominal cavities and is innervated by the phrenic nerve. When stimulated, the diaphragm contracts downward, decreasing intrapleural pressure by approximately 2–3 mmHg, thereby expanding the thoracic cavity and, in turn, the lungs. This allows atmospheric air to flow inward. The external intercostal muscles, located between the ribs, assist by elevating the ribs and sternum, expanding the thoracic cavity outward and forward. As exercise intensity increases, the rate and amplitude of these movements rise, leading to an increase in both breathing frequency (breaths per minute) and tidal volume (the volume of air moved during a normal breath). Consequently, minute ventilation also increases. From a mechanical perspective, breathing can be classified as thoracic or abdominal. Thoracic breathing is primarily driven by the intercostal muscles (*m. intercostalis externi et interni*), while abdominal breathing is dominated by the diaphragm. Additional muscles—such as the *m. transversus thoracis*, *m. pectoralis major/minor*, *m. levatores costarum*, *m. erector spinae*, *m. subcostalis*, *m. scalenes*, and *m. sternocleidomastoideus*—also play direct or supportive roles in respiration. These two breathing modes operate simultaneously and cannot be completely separated (Weineck, 2002).

Stretching Exercises

Stretching is a process aimed at elongating muscle fibers by mobilizing connective tissue. It enhances flexibility and joint range of motion through externally or internally applied forces acting on muscle attachment points (Baltacı, Bayrakcı, Besler, & Ergur, 2016). Muscles involved in movement are prone to temporary or chronic impairments caused by sudden loads, aging, or fatigue (Frontera & Ochala, 2015). Even a single session of stretching can prevent such dysfunctions and improve joint mobility (Nakamura et al., 2021). Research investigating the long-term effects of stretching on muscle structure and function indicates that increased duration of stretching exercises enhances both muscle adaptability and functional capacity (Siatras et al., 2008). Although tendons and muscles are inherently elastic, sudden overstretching during exercise can lead to injury—particularly in athletes. Maintaining both flexibility and strength in these tissues is key to minimizing such risks (Toft et al., 1989).

Physiological Mechanisms of Stretching

Biomechanical Mechanism

Muscles are composed of tendons, nerves, blood vessels, fascia, and muscle fibers. These

structures possess a highly complex organization, and among them, muscle and nerve cells exhibit electrical properties. However, in order for the muscles to enter a resting state, the active electrical charge must become negative, preventing the transmission of electrical signals between cells. For such transmission to occur, neurotransmitters are involved, whose role is to establish connections with neurons or muscle cells and release specific chemicals. Stretching exercises lead to the elongation of muscle fibers, with the initial effect occurring at the sarcomere, which is the structural and functional unit of the muscle (Nelson & Kokkonen, 2013). The sarcomere, composed of actin and myosin filaments, maintains these two filaments side by side in a resting state, overlapping within the muscle. As muscles contract and become active, the interaction between actin and myosin increases (Mukund & Subramaniam, 2020). During the application of a stretching exercise, the interaction between myosin and actin decreases compared to the resting state, resulting in an increase in muscle fiber length. From another perspective, stretching improves the viscoelastic properties of the muscle-tendon unit, leading to elongation of the muscle, which is considered a fundamental biomechanical feature of stretching (Medeiros & Lima, 2017).

Neurological Mechanism

Nerve endings, known as proprioceptors, transmit all information from the musculoskeletal system to the Central Nervous System (CNS). Also referred to as mechanoreceptors, proprioceptors detect stretch, force, and positional changes. Proprioceptors are present in the nerve endings of all joints, muscles, and tendons throughout the body. In the context of stretching, the relevant proprioceptors are located within muscle fibers and tendons (Behm & Wilke, 2019). When considering the neurological mechanism of stretching, many researchers have examined changes in the Hoffmann reflex. This type of reflex is elicited by the electrical stimulation of a peripheral nerve. To activate motor neuron axons, alpha motor neurons and a monosynaptic connection are required. This connection becomes possible immediately before the Hoffmann reflex is elicited through the induction of M-waves. A reduction in the Hoffmann reflex following stretching provides information regarding postsynaptic and presynaptic changes. Presynaptic changes may be associated with presynaptic inhibition, which leads to an autonomic decrease in Ia afferents, while postsynaptic changes may result from autonomic inhibition via the Golgi tendon organ or Renshaw recurrent inhibition (Guisard, Duchateau, & Hainaut, 2001). For muscles to function properly and harmoniously, the activation of anterior motor neurons in the spinal cord alone is insufficient. All active muscles must continuously provide feedback to the spinal cord. How is this achieved? This is accomplished by sensory receptors responsible for providing sensory feedback. There are three primary muscle sensory organs responsible for perceiving kinesthetic sense: the Golgi tendon organ, the muscle spindle, and joint receptors (Guyton & Hall, 2007).

Respiratory Muscle Stretching Exercise

Possessing an efficient respiratory mechanism depends on chest mobility, adequately functioning respiratory muscles capable of generating sufficient lung volumes, and the ability to move effectively for proper pulmonary ventilation (Sonehara et al., 2011). Respiratory impairments often result from shortening within the respiratory muscle system. Structural and morphological changes in the chest wall, in particular, can lead to a 30–40% shortening of respiratory muscle fibers. Consequently, an imbalance occurs in the tension–length relationship, limiting thoracic expansion. This insufficient expansion affects costal mobility and reduces pulmonary function. Stretching exercises for respiratory muscles are believed to mitigate this adverse effect, as they directly elongate muscle fibers and are highly effective in increasing thoracic mobility (De Troyer, 2012). Additionally, these exercises promote adaptations in the muscle-tendon unit. By increasing the distance between the origin and insertion of the diaphragm, they reduce the tension caused by fiber shortening and facilitate more effective muscle contraction (Page, 201). Respiratory muscle stretching exercises can be applied acutely or chronically. Acute interventions are administered as a single session (Aguilar et al., 2016). Chronic programs typically range from 1 to 12 weeks, with applications performed two to three times per week. Session duration varies between 20 and 60 minutes. Passive stretching and muscle relaxation techniques are predominantly employed in this method (Häkkinen, Kautiainen, Hannonen, & Ylinen, 2008).

The muscles targeted in respiratory stretching exercises include the diaphragm, scalenes, pectoralis minor and major, serratus anterior, sternocleidomastoid, intercostals, and rectus abdominis. Previous studies have reported that even isolated intercostal stretching exercises improve vital capacity, reduce dyspnea levels, and clinically enhance thoracic expansion (Mohan et al., 2012). In animal studies, weekly stretching of shortened muscles was sufficient to reduce muscle atrophy, while stretching three times per week resulted in increased muscle fiber cross-sectional area and a higher number of sarcomeres (Coutinho et al., 2004). At the same time, when looking at human studies, various improvements have been observed in respiratory functions and respiratory muscle parameters in proper breathing exercises or diaphragm-focused breathing exercises (Vural et al., 2024; Yang et al., 2022).

Acute Effects of Stretching Exercises

When a muscle or group of muscles is passively stretched, short-term changes may occur within the muscle. These acute or short-term effects are primarily related to performance alterations observed during the initial hours following stretching. In some performance parameters, such as strength, a temporary decrease may be noted, whereas in others, such as joint range of motion (ROM), improvements can be observed. Acute stretching affects the viscoelastic properties of the muscle, resulting in an increase in muscle-tendon length

(Knudson, 2006). From a neurophysiological perspective, acute stretching elicits muscle reflexes, which are subsequently inhibited, reducing resistance and contributing to an increase in ROM (Budini et al., 2019). The speed of stretching is an important factor: higher stretching velocities result in greater muscle stiffness, whereas slow stretching generates less passive tension compared to rapid stretching (Sharman, Cresswell, & Riek, 2006).

It is generally recommended that stretching exercises be held for 20 to 30 seconds. This duration allows passive tension within the muscle to diminish over a certain range of motion, thereby reducing or eliminating stress on the muscle. The reduction or removal of this stress typically occurs within approximately 20 seconds (Duong et al., 2001). The effects of acute stretching vary depending on the type, duration, and frequency of the applied exercise. Notably, proprioceptive neuromuscular facilitation (PNF) stretching increases pain thresholds and produces an analgesic effect (Câmara-Gomes et al., 2022).

Although research does not provide definitive evidence that acute stretching directly reduces muscle stiffness, one of the most effective methods to achieve this is through warm-up protocols that increase muscle temperature prior to performance. Recent studies have reported mixed results: Taniguchi et al. observed temporary reductions in gastrocnemius muscle stiffness following static stretching (Taniguchi et al., 2015), whereas Hirata et al. found that only the stiffest muscles within the triceps surae group exhibited decreased stiffness after stretching (Hirata et al., 2016). Another variable to consider when examining the acute effects of stretching is muscle strength. Walsh et al. reported that dynamic stretching positively influences muscle strength more than static stretching and recommended that dynamic stretching be preferred in pre-performance warm-up protocols (Walsh, 2017). A recent systematic review highlighted that due to heterogeneity in procedures and outcome measures, achieving a consensus regarding the effects of stretching on maximal muscle performance is challenging (Mine et al., 2016).

Chronic Effects of Stretching Exercises

Chronic, or long-term, stretching exercises play an important role in enhancing force production by reducing inhibition within the neuromuscular system (Dallas et al., 2014). The physiological mechanisms underlying long-term stretching include an increase in sarcomere number, a reduction in muscle stiffness, and improved calcium ion function within the neuromuscular system. Regarding events that can enhance energy efficiency, decreases in muscle-tendon stiffness or improved compliance reduce resistance to movement. Energy efficiency is also directly associated with heat loss and viscoelastic changes in tissues that influence stretching (Kubo, 2005). Previous studies have consistently reported that long-term stretching improves flexibility across all types of stretching interventions. In several studies, stretching programs applied to various

muscle groups over three to six weeks resulted in approximately a 12° improvement in range of motion (ROM) (Kataura et al., 2017). Moreover, Konrad et al. reported that six weeks of PNF stretching increased joint ROM and reduced tendon stiffness (Guissard & Duchateau, 2004). Chronic elongation of muscles due to stretching is thought to be related to the myogenic response of sarcomeres (Decoster et al., 2005). Chronic and regular stretching has also been associated with a reduction in injury risk (Konrad, Gad, & Tilp, 2015). However, the long-term effects of stretching on muscle-tendon properties and muscle strength have not been fully clarified. In a four-week study, stretching positively influenced flexibility, but this effect was attributed more to changes in pain perception rather than alterations in the physical properties of the muscle-tendon unit (Gajdosik, 2001). A systematic review of fourteen studies examining the chronic effects of stretching on muscle performance indicated that long-term stretching positively affected functional tests and isotonic contractions but did not show significant effects on isometric contractions. This finding highlights the need for further research to investigate the chronic impact of stretching on muscle performance (Muanjai et al., 2017).

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About the Authors

Lecturer Mustafa Burak CAĞDANLIOĞLU graduated from Gaziantep University School of Physical Education and Sports, Department of Coaching Education in 2014. In 2021, he completed his master's degree at Gaziantep University Institute of Health Sciences, Department of Physical Education and Sports. He has been continuing his doctorate education at Gaziantep University since 2021. His research interests include soccer, training and movement science.

E-mail: mustafacoglu@hotmail.com, ORCID: 0000-0002-2185-2339

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