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Mechanistic And Molecular Insights Into The Effects Of Yoga Asanas, Pranayama, Kriyas, And Meditation On Respiratory Health

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Abstract

Background: Respiratory diseases are driven by mechanical dysfunction, autonomicimbalance, and chronic inflammation. Yoga asanas, pranayama, kriyas, and meditation exert mechanical and neuro-immune effects underpinned by molecular changes. The main objective is to delineate mechanistic, clinical, and molecular pathways through which yogic practices and meditation modulate respiratory function. A narrative synthesis of systematic reviews, clinical trials, and molecular studies assessing respiratory outcomes, autonomic measures, inflammatory markers, and gene expression is processed. Yogic interventionsnimprovesspirometric indices, respiratory muscle performance, airway clearance, autonomicnregulation, and reduce inflammatory cytokines (IL-6, TNF-α), upregulate anti-inflammatorynIL-10, and modulate stress-response genes (NR3C1, NF-κB). Incorporating Yoga practices innrespiratory care yields synergistic benefits; future work should quantify molecular mediators and standardize protocols.

Keywords: Yoga, Meditation, Respiration, Pulmonary, Inflammation.

Introduction

Airflow restriction, airway hyperresponsiveness, and chronic inflammation are the hallmarks of respiratory disorders, including asthma and COPD , which impacts more than 500 million people worldwide. Although standard medication treats symptoms, it is frequently unable to alter chronic inflammatory processes or mechanical limitations. A mind-body discipline that includes asanas (postures), pranayama (breath management), kriyas (cleaning exercises), and meditation, yoga provides a holistic therapy that targets mucociliary, autonomic, mechanical, and molecular pathways. In addition, yogic therapies have been shown to improve lung function and quality of life in patients with COPD by modifying molecular indicators of inflammation and oxidative stress.(Thokchom et al., 2018) According to research, individuals with mild asthma who followed a systematic yoga practice that included asanas, pranayama, and meditation showed notable increases in their FVC , MVV , and PEFR , all of which indicate increased lung capacity, respiratory muscle strength, and airflow.(Anshu&Pintu Kumar Mahto, 2022; BahçecioğluTuran& Tan, 2020; Kumar, 2025)

Mechanistic Pathways

1. Autonomic and Neuroendocrine Regulation

Meditation and slow pranayama improve bronchial smooth muscle relaxation and lower airway resistance by increasing vagal efferent activation.(Jayawardena et al., 2020; Karunarathne et al., 2024) Cortisol and catecholamine release are decreased when the hypothalamic-

pituitary-adrenal (HPA) axis activity is downregulated, which also lessens airway inflammation.(Jayawardena et al., 2020; Karunarathne et al., 2024)

2. Respiratory Muscle Conditioning and Surfactant Dynamics

Tidal volume and maximal inspiratory pressure are increased by asanas and strong pranayama, which also improve inspiratory/expiratory muscle mitochondrial biogenesis.(Anshu et al., 2023; Carter & III, 2016) In pranayama, deep alveolar stretch triggers the release of surfactant from type II pneumocytes, which reduces surface tension and enhances lung compliance.(Carter & III, 2016; Jayawardena et al., 2020)

3. Airway Clearance via Kriyas

Nasal irrigation (JalaNeti) lessens mucosal oedema and increases the synthesis of nitric oxide for vasodilation; rapid abdominal thrusts in Kapalabhatimobilise bronchial secretions.(Carter & III, 2016; Zaccaro et al., 2018)

4. Ventilation–Perfusion Optimization

By reducing physiological dead space, prolonged exhalation patterns enhance gas exchange and alveolar ventilation.(Karunarathne et al., 2024) Nitric Oxide Mediated Vasodilation is characterised by increased nasal NO that diffuses to pulmonary arteries, coordinating breathing and perfusion.(Carter & III, 2016)

5. Chemoreceptor and Baroreceptor Sensitivity

Deeper, slower breaths are made possible by slow diaphragmatic breathing, which reduces central chemoreceptor sensitivity to CO2 .(Jayawardena et al., 2020; Karunarathne et al., 2024) In order to optimise heart-rate variability and respiratory sinus arrhythmia, improved baroreceptor feedback synchronises cardiac–respiratory oscillations.(Jayawardena et al., 2020; Karunarathne et al., 2024)

6. Molecular and Anti-Inflammatory Mechanisms

To mitigate airway inflammation, regular pranayama and meditation raise levels of the anti-inflammatory cytokine IL-10 while decreasing levels of the pro-inflammatory cytokine IL-6 and TNF-α .(Carter & III, 2016; Jayawardena et al., 2020) In airway epithelial cells, yogic practices decrease NF-κBsignalling, which lowers the expression of inflammatory mediators and adhesion molecules.(Carter & III, 2016)

Gene Expression and Epigenetics: In addition to modifying histone deacetylase activity to inhibit the transcription of inflammatory genes, meditation increases the expression of the glucocorticoid receptor gene (NR3C1), which strengthens endogenous anti-inflammatory responses.(Jayawardena et al., 2020)

Oxidative Stress Reduction: Increased activity of antioxidant enzymes (catalase, superoxide dismutase) after yoga practice reduces reactive oxygen species in lung tissue.(Carter & III, 2016)

Clinical and Functional Outcomes

FVC , FEV_1 , and PEFR have been demonstrated to rise in both healthy and ill individuals when yogic programs incorporating these principles are used.(Chahal et al., 2023; Negi et al., 2024) In individuals with COPD, yoga increases exercise tolerance and 6-minute walk distance, lowers medication reliance, improves mucociliary clearance, and decreases the occurrence of respiratory infections.(Liu et al., 2014)

Conclusion

Yoga and meditation are powerful adjuncts in respiratory therapy because of their synergistic effects of airway cleansing, autonomic rebalancing, mechanical strengthening, and molecular anti-inflammatory modulation. The observed clinical improvements have a biological basis due to molecular changes, including cytokine shifts, transcription factor modulation, and epigenetic modifications. Through the use of mechanical, autonomic, mucociliary, and molecular routes, the integration of organised asanas,

pranayama, kriyas, and meditation results in comprehensive respiratory benefits. To maximise therapeutic applications, future randomised studies with standardised protocols and biomarker analysis are crucial.

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