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BREATHING FOR PERFORMANCE: NASAL FUNCTION, OBSTRUCTION, AND THERAPEUTIC INTERVENTIONS IN COMPETITIVE ATHLETES

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ABSTRACT

Background: nasal respiration is the only true physiological breathing mechanism, providing essential ventilation, air conditioning, and defensive filtration for the lower airways. For professional athletes, rhinosinusal health is one of the determinants of performance, yet sport-specific environments often disrupt this homeostasis, leading to a clinical state often described as the "athlete's nose".

Purpose: to evaluate the pathophysiology of exercise-induced rhinosinusal alterations across various sport categories and to synthesize evidence-based management strategies - incorporating mechanical, surgical, and pharmacological interventions - to optimize athletic performance and cardiovascular safety.

Methods: a structured literature review was conducted with reference to PRISMA guidelines for search transparency. Data were synthesized from clinical studies involving professional athletes (swimmers, skiers, runners, and boxers) and compared against established assessment protocols, including, the International Consensus Statement on Rhinosinusistis (ICAR-RS 2021), EPOS 2020, and the SARAH assessment framework. Findings were narratively synthesized by sport-specific pathophysiology.

Results: significant alterations in nasal physiology were identified. Swimmers showed the most severe deviations, with a mean mucociliary transport time (MCTt) of 27.4±4.97 min compared with the 13-minute norm ($p<0.0001$), linked to chlorine-induced neurogenic inflammation and elevated Substance P. Nasal breathing was found to enhance physical endurance and may protect against cardiac fibrosis by reducing sympathetic drive. Interventions, including internal nasal dilators, septoplasty, and post-operative topical furosemide, showed significant benefits for performance and symptom control.

Conclusions: rhinosinusal disruptions are sport-specific and significantly impair physical capacity. Multimodal management and systematic screening are essential for maintaining competitive fitness.

KEYWORDS

Athletes; Nasal Breathing; Rhinosinusitis; Mucociliary Transport Time; Sports Performance

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1. Introduction.

Nasal respiration is widely recognized as the primary physiological pathway for human ventilation. Beyond simple gas exchange, the nose serves as a sophisticated air conditioner, warming and humidifying inspired air while acting as a first-line immunological filter (Bonini et al., 2006; McIntosh et al., 2021). For professional athletes, these roles are vital, given that high physical performance depends on proper nasal function that remains strictly proportional to the intensity of training efforts (Passàli et al., 2004).

The concept of the "athlete's nose" describes a unique clinical state where training environments, ranging from chlorinated pool chemicals to sub-zero alpine trails, predispose competitors to recurrent infections, inflammation, and respiratory compromise (Passàli et al., 2004; Surda et al., 2019). Indeed, exercise-induced rhinitis (EIR) affects the majority of athletes, with 61% reporting symptoms during indoor exercise and 56% during outdoor activity (Silvers & Poole, 2006). Acute respiratory illness is now recognized as one of the leading causes of competition- and training-loss in elite participants (Hull et al., 2021; Keleş, 2002; McIntosh et al., 2021). Furthermore, emerging research suggests the mode of breathing impacts the Euler-Liljestrand mechanism, where nasal obstruction can influence pulmonary artery pressure and functional overload of the heart ventricles (Brzoza & Matusiak, 2026).

Research objective. This review aims to systematically analyse how sport-specific stressors disrupt upper airway physiology and to identify evidence-based management pathways tailored to the athletic population.

Research problems. How do environmental triggers (chlorine, cold air, trauma) alter mucociliary clearance and nasal patency in elite athletes? What is the measurable impact of nasal obstruction on aerobic performance, physiological economy, and cardiovascular safety?

Research hypotheses. Chronic exposure to specific training environments leads to a pathological prolongation of mucociliary transport time (MCTt). Restoration of nasal patency through mechanical dilators or surgical intervention improves VO2max efficiency, thus enhancing aerobic performance, and protecting against cardiac remodeling.

2. Methodology.

2.1. Study design.

This study presents a structured narrative review synthesizing evidence on sport-specific rhinosinusal alterations in professional athletes. The review was conducted with reference to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines for search transparency and reporting clarity, though the methodology reflects a narrative synthesis rather than a formal systematic review or meta-analysis.

2.2. Search strategy.

A structured literature search was performed across three electronic databases: Medline (via PubMed), Embase, and Web of Science. The search covered publications from January 2000 to December 2025 to capture both foundational and contemporary evidence.

2.3. Inclusion and exclusion criteria.

Studies were considered for inclusion if they met the criteria listed in Table 1.

Table 1. Inclusion criteria applied in the literature search.

Criterion	Description
Population	Professional or elite-level athletes (swimmers, skiers, runners, boxers, or mixed cohorts)
Intervention/exposure	Sport-specific training environment (chlorine exposure, cold air, trauma, high ventilation)
Outcomes	Mucociliary transport time (MCTt), nasal resistance (rhinomanometry), rhinitis prevalence, or performance measures (VO_2max, time to exhaustion)
Study design	Original research (cohort studies, cross-sectional studies, case-control studies); systematic reviews and consensus statements were used for background
Language	English
Publication date	2000-2025

Exclusion criteria:

- studies involving recreational or non-elite athletes without clear subgroup stratification
- case reports or case series with fewer than 5 participants
- animal models or in vitro studies without clinical correlation
- editorials, commentaries, or conference abstracts without full-text availability.

2.4. Quality appraisal.

Given the narrative design, formal risk of bias assessment using standardized tools (e.g., ROBINS-I, QUADAS-2) was not performed. However, included studies were evaluated for methodological transparency, sample size adequacy, and appropriateness of outcome measures. Priority was given to studies with validated rhinological instruments (MCTt, rhinomanometry) and clearly defined athlete populations.

2.5. Synthesis approach.

Findings were synthesized narratively according to sport-specific subgroups (swimmers, skiers, runners, boxers), reflecting the distinct pathophysiological mechanisms reported in the literature. Quantitative data (MCTt means, standard deviations, p-values) are reported as originally presented in source studies. No meta-analytic pooling was performed.

3. Research results.

3.1. Subgroup pathophysiology.

Sport-specific paradigm stressors result in distinct clinical pictures of rhinosinusal disruption:

Professional swimmers (aquatic sports). Exposure to chlorine and pool vapours causes chronic inflammation and submucosal oedema (Bonini et al., 2006; Passàli et al., 2004). Swimmers exhibited the most severe deviations: a mean MCTt of 27.4±4.97 minutes ($p<0.0001$), with 10% exceeding 30 minutes (Passàli et al., 2004). This is linked to elevated Substance P (neurogenic inflammation) and uric acid (epithelial injury) in nasal secretions (Steelant et al., 2018). In symptom-driven cohorts, 33% of elite swimmers suffered from non-allergic rhinitis (NAR), a condition formally defined by the EAACI position paper as chronic nasal symptoms without systemic IgE-mediated inflammation (Hellings et al., 2017; Surda, Putala, et al., 2018). Allergic rhinitis, as described by Keleş (2002), presents a parallel management challenge in athletic populations, though its triggers differ from the chlorine-induced inflammation seen in swimmers (Keleş, 2002).

Professional skiers (cold-weather sports). Serving as a model of cold-induced rhinorrhea ("skier's nose"), skiers demonstrated a significantly prolonged MCTt of 19.58±1.92 minutes ($p<0.001$). Positive nasal decongestion tests (NDT) normalized resistance, confirming a vasomotor origin (Bonini et al., 2006; Passàli et al., 2004).

Professional boxers (combat sports). Alterations are predominantly traumatic. Nasal pyramid fractures and septal trauma resulted in a mean total resistance of 0.64±0.05 Pa/ml/s, more than double the norm. Moreover, the mean MCTt was 27.35±2.21 minutes ($p<0.0001$), attributed to structural disruption of the nasal valve and subsequent impairment of mucociliary clearance (Bonini et al., 2006; Passàli et al., 2004).

Professional runners (endurance sports). High minute ventilation and dehydration force a turbinate congestion-decongestion cycle, leading to "runner's nose" and an MCTt of 20.56±2.35 minutes ($p<0.001$) (Bonini et al., 2006; Passàli et al., 2004).

Comparison of the MCTt between research subgroups is displayed in Figure 1.

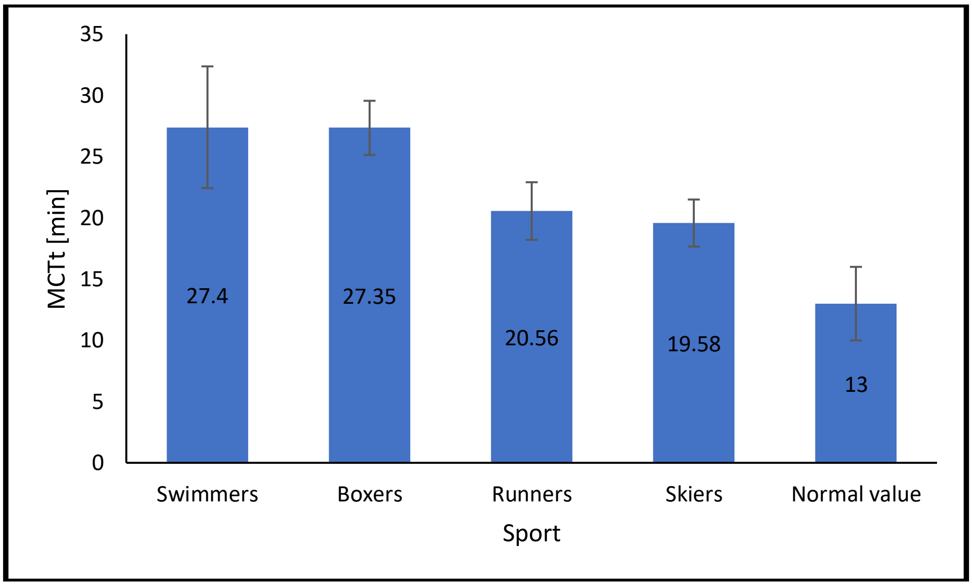

Fig. 1. *Comparison of the mean MCTt [minutes] by sport (1,3).*

3.2. Breathing mechanics and the "Switching Point".

Athletes typically switch from nasal to oronasal breathing at a minute ventilation (VE) of 35–45 L/min (Gehring et al., 2000; Lacomb, 2015; McIntosh et al., 2021; Raphael et al., 2024). This point is pathologically shifted towards lower intensities in those with structural obstruction, depriving them of the metabolic benefits of nasal breathing (Brzoza & Matusiak, 2026). Interestingly, adapted nasal breathers achieve the same VO2max while ventilating 22% less. This is attributed to improved ventilation-perfusion matching from nasal nitric oxide, significantly reducing the metabolic cost of breathing (Brzoza & Matusiak, 2026; Dallam & Kies, 2020; Raphael et al., 2024).

3.3. Impact on performance and physiological economy.

<u>Physiological economy.</u> Nasal breathing reduces the respiratory rate (RR) and central sympathetic drive (Brzoza & Matusiak, 2026; Dallam & Kies, 2020; Raphael et al., 2024). Calamai et al. (2023) established that nasal breathing improves ventilatory efficiency in patients with cardiac disease, suggesting similar potential for athletic recovery (Calamai et al., 2023).

<u>Maximal effort.</u> Bergqvist et al. (2025) found that while VO2max was similar across modes of breathing, Time to Exhaustion (TTE) was 4.2% longer during decongested oronasal breathing compared to oral-only breathing, suggesting a subtle but meaningful benefit in competitive settings (Bergqvist et al., 2025).

<u>Lactate accumulation.</u> Oral-only breathing was associated with lower post-exercise blood lactate, but this likely reflects the shorter exercise duration rather than metabolic superiority (Bergqvist et al., 2025).

3.4. Management and intervention strategies.

<u>Nasal dilators.</u> Adhesive external nasal dilator strips (ENDS) stiffen the lateral vestibule walls, reducing flow-resistive work and delaying the oronasal switching point (Dallam & Kies, 2020; Gehring et al., 2000).

<u>Septoplasty.</u> For athletes with structural deviation, surgical restoration acts as a key intervention bridging the physiological gap between the athlete and fit rivals (Brzoza & Matusiak, 2026).

<u>Pharmacological protocols (ICAR-RS 2021/EPOS 2020).</u>

Saline irrigation. Grade A recommendation for all cases of chronic rhinosinusitis (CRS), as defined by EPOS 2020, improving quality of life when used for >8 weeks (Fokkens et al., 2020; Orlandi et al., 2021).

Topical Furosemide. Post-operative application significantly reduces the recurrence of nasal polyps to 17.5%, compared to 30% in untreated groups (Orlandi et al., 2021; Passàli et al., 2003).

Corticosteroids (INCS). Strongly recommended before and after surgery to control mucosal inflammation (Fokkens et al., 2020; Orlandi et al., 2021).

The clinical necessity for these interventions is highlighted by the finding that exercise-induced rhinitis adversely impacts athletic performance in 40% of affected athletes, rising to 53% in those with underlying allergy, directly influencing their ability to train and compete effectively (Silvers & Poole, 2006).

4. Discussion.

The concept of the "athlete's nose" represents a unique clinical diagnosis at the intersection of otolaryngology and high-performance sports medicine. While the general population utilizes nasal respiration for basic health maintenance, for the elite athlete, nasal patency is a precondition for reaching peak endurance capacity (Brzoza & Matusiak, 2026; Passàli et al., 2004). The findings of this review demonstrate that exercise-induced alterations are not uniform but are dictated by the specific environmental stressors of the sport: chemical (swimmers), thermal (skiers), traumatic (boxers), and hyperpneic/dehydrating (runners) (Passàli et al., 2004; Surda, Putala, et al., 2018).

4.1. Pathophysiological mechanisms.

The most striking finding is the constant prolongation of mucociliary transport time (MCTt) across all elite athletic groups, particularly swimmers and boxers, where mean values exceeded 27 minutes (Passàli et al., 2004). In aquatic athletes, this failure of the defensive "filter" is likely driven by delayed neurogenic inflammation, a key mechanism in non-allergic rhinitis where irritants trigger sensory nerve activation and neuropeptide release (Hellings et al., 2017; Steelant et al., 2018). Chronic exposure to chlorine and its by-products (trichloramines) disrupts epithelial tight junctions, triggering the release of Substance P and uric acid - markers of epithelial injury that facilitate the penetration of allergens and the migration of inflammatory cells (Steelant et al., 2018; Surda, Putala, et al., 2018). For winter athletes, the "skier's nose" serves as a model of cold-induced rhinorrhea, where low temperatures trigger a parasympathetic reflex followed by vasomotor congestion of the nasal conchae (Passàli et al., 2004).

4.2. The performance-breathing paradox.

Historically, exercise physiology assumed that oral breathing was superior for maximal effort due to lower resistance (Dallam & Kies, 2020). However, recent evidence suggests that maintaining nasal breathing for as long as possible provides an advantage in physiological economy (Brzoza & Matusiak, 2026). Adapted nasal breathers achieve the same VO2max as oral breathers while ventilating approximately 22% less, thereby reducing the metabolic cost of breathing and sparing oxygen for the locomotor muscles (Brzoza & Matusiak, 2026; Raphael et al., 2024).

The "switching point" from nasal to oronasal breathing, typically occurring at a minute ventilation of 35–45 L/min, is a critical performance marker (Brzoza & Matusiak, 2026; Lacomb, 2015; Raphael et al., 2024). In athletes with structural deficits like nasal septal deviation (NSD), this point shifts pathologically towards lower intensities, depriving the athlete of humidified air and the transport of sinonasal-derived nitric oxide (NO) to the lungs (Brzoza & Matusiak, 2026). NO acts as a local vasodilator that improves ventilation-perfusion matching and can increase arterial oxygenation by 10-20% (Bergqvist et al., 2025; Brzoza & Matusiak, 2026).

4.3. Cardiovascular protection.

A compelling hypothesis suggests that nasal breathing may protect athletes from exercise-induced cardiac fibrosis and arrhythmias. Chronic oral hyperventilation leads to hypocapnia, which triggers coronary vasoconstriction and myocardial hypoxia (Orlandi et al., 2021; Raphael et al., 2024). Conversely, nasal breathing increases end-tidal CO2 (PETCO2), acting as a natural vasodilator that improves myocardial perfusion while reducing sympathetic drive and respiratory rate. Furthermore, the Euler-Liljestrand mechanism indicates that nasal obstruction can increase pulmonary artery pressure, leading to functional overload of the heart ventricles (Brzoza & Matusiak, 2026; Raphael et al., 2024).

4.4. Management.

Management must be multi-modal and stratified by the athlete's career stage.

<u>Mechanical:</u> For athletes with nasal valve compromise, internal nasal dilators are proven to improve aerobic performance and delay the oronasal switching point (Dallam & Kies, 2020; Gehring et al., 2000).

<u>Surgical:</u> Septoplasty acts as a key intervention to optimize respiratory potential, eliminating the physiological gap between the athlete and their fit rivals (Brzoza & Matusiak, 2026).

<u>Pharmacological:</u> Standardized adherence to the ICAR-RS 2021 and EPOS 2020 protocols is essential. For non-allergic phenotypes specifically, the EAACI position paper emphasizes the efficacy of intranasal corticosteroids and saline irrigation, while noting that antihistamines may be less effective than in allergic rhinitis (Hellings et al., 2017). Saline irrigation (>60ml) and intranasal corticosteroids (INCS) are first-line therapies (Grade A/B). Notably, post-operative topical furosemide significantly reduces the recurrence of nasal polyps by treating oedematous infiltrate (Fokkens et al., 2020; Orlandi et al., 2021; Passàli et al., 2003).

4.5. The systematic imperative.

The high prevalence of unrecognized modifiable respiratory issues, identified in 80% of elite athletes via the SARAH assessment, highlights the need for proactive screening in high-performance programs (Hull et al., 2021). Early intervention prevents the development of "rhinobronchial syndrome" (where untreated or prolonged pathologies of the superior airways are pathologically linked to the onset or worsening of more serious inferior airway diseases) and limits the loss of training and competition days to acute respiratory illness (McIntosh et al., 2021; Passàli et al., 2004). Researchers must now focus on the "topical paradox": while systemic treatments succeed in acute settings, topical therapies for athletes must be specifically formulated to withstand the high-flow ventilation environments inherent to sport (Orlandi et al., 2021).

4.6. Limitations

The findings in this review are significantly influenced by the landmark study by Passàli et al. (Passàli et al., 2004), which, while foundational, may not fully represent contemporary athlete populations or training environments. Moreover, no formal risk of bias assessment was performed on included studies, which may affect the interpretability of pooled clinical impressions. Additionally, the narrative synthesis approach precludes meta-analytic estimation of effect sizes across interventions. Finally, the exclusion of non-English publications may introduce language bias.

5. Conclusions.

5.1 Prevalence and sport-specific pathophysiology.

Exercise-induced rhinosinusal alterations are not merely common but are strictly dictated by the specific environmental and physiological stressors of each sport. Professional athletes, particularly swimmers, demonstrate the most severe deviations in nasal physiology, characterised by a significantly prolonged mean mucociliary transport time (MCTt: 27.4±4.97 minutes) (Passàli et al., 2004; Steelant et al., 2018). This impairment is driven by neurogenic inflammation and epithelial injury caused by chronic exposure to chlorine and hypochlorite, as evidenced by elevated Substance P and uric acid levels (Orlandi et al., 2021; Steelant et al., 2018). Conversely, skiers present a model of cold-induced vasomotor rhinitis, while boxers suffer from predominantly traumatic disruptions that double clinical nasal resistance norms (Passàli et al., 2004; Surda, Walker, et al., 2018).

5.2 Physiological economy and performance impact.

Maintaining nasal patency is a foundational determinant of exercise economy. Adapted nasal breathers can achieve the same oxygen consumption (VO2max) as oral breathers while ventilating approximately 22% less, thereby reducing the metabolic cost of respiratory muscle work and sparing oxygen for locomotor muscles (Brzoza & Matusiak, 2026; Dallam & Kies, 2020). Furthermore, while absolute VO2max may remain stable across breathing modes, oronasal breathing with a decongested nose has been shown to increase TTE by 4.2%, a critical margin in competitive endurance sports (Gehring et al., 2000).

5.3 Cardiovascular protection and sympathetic regulation.

Nasal breathing during high-intensity exercise provides more than just comfort - it acts as a protective physiological mechanism. By reducing the respiratory rate and central sympathetic drive, nasal breathing may inhibit the development of cardiac fibrosis and arrhythmias associated with long-term endurance training. The accompanying increase in end-tidal CO2 (PETCO2) serves as a natural vasodilator, improving myocardial blood flow and potentially mitigating exercise-induced cardiac strain (Orlandi et al., 2021; Raphael et al., 2024).

5.4 Hierarchy of management strategies.

Management of the "athlete's nose" must be multi-modal and evidence-based. Internal and external nasal dilators are effective mechanical tools for reducing flow-resistive work and delaying the oronasal "switching point" (Gehring et al., 2000; McIntosh et al., 2021). Septoplasty acts as a critical determinant bridging the physiological gap between symptomatic athletes and their fit rivals by normalizing cardiac hemodynamics and regenerative potential (Brzoza & Matusiak, 2026). Pharmacological care should strictly adhere to the management protocols outlined in ICAR-RS 2021 and EPOS 2020, prioritizing large-volume saline irrigation, intranasal corticosteroids (INCS), and topical furosemide to prevent post-operative polyp recurrence (Fokkens et al., 2020; Orlandi et al., 2021).

5.5 Clinical implementation and systematic screening.

Given that up to 80% of elite athletes may harbour unrecognized modifiable respiratory health issues, the integration of systematic assessment protocols, such as the SARAH process, into high-performance programs is indispensable. Early identification of "rhinobronchial syndrome" prevents training loss and competition-day failure (Hull et al., 2021; McIntosh et al., 2021). Future research must address the "topical paradox" by developing formulations that optimize mucosal residence time in the high-flow ventilation environments inherent to professional sport (Orlandi et al., 2021).

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