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REVIEW ARTICLE

Nasal function and dysfunction in exercise

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Abstract

Background: There have been recent advances in our appreciation of the functional complementarity of the upper and lower airways. The unified airway begins at the nose: rather than acting merely as a conduit for air to the lungs, the nose and nasal cavity perform an important role in filtering, humidification and immune surveillance.

Methods: The physiological and pathological responses of the nasal cavity to exercise and regular training are examined in this narrative review, with specific reference to the relation of nasal health to quality of life, lower airway health and upper respiratory tract infections. Relevant literature is examined and placed in clinical context.

Results: There is considerable published evidence to support nasal dysfunction associated with exercise, and a link to lower airway dysfunction. Evidence also supports the role of upper and lower airway dysfunction in the development of upper respiratory tract infection symptoms.

Conclusion: Nasal dysfunction in exercise may be a source of considerable morbidity to the regular exerciser, and further research into exercise-induced rhinitis is recommended.

Key words: Rhinitis; Exercise; Nose; Athletes; Physiology; Sports Medicine; Nasal Obstruction

Introduction

'Winning by a nose' is a phrase that reflects the fine margins of sport where inches may separate first and second place. And yet, could the nose play a more important role in peak performance than just as a prominent point to take the tape at photo finishes? Nasal function may seem of little consequence to athletic ability, but a growing breadth of evidence supports the integration of nasal physiology with the lower airways. This perception of a single 'unified airway' is clearly of fundamental importance to performance. This review aimed to: investigate the physiology of the nose during exercise, examine the relationship between exercise and nasal dysfunction, and consider the impact that dysfunction may have on an athlete.

Normal nasal physiology

At rest, humans are predominantly nose-breathing animals. The mucosal surface area of the nose is not an inert highway to the lower airway: it is metabolically and functionally active. It acts as a heat and moisture exchanger for cold and dry atmospheric air; it is the site of the immune 'first response' to antigens entering the body via the air stream; it filters microparticulate matter from the airstream; and it absorbs up to 95 per cent of gases that are water soluble or very reactive (e.g. ozone, sulphur dioxide).[1] Thus, in resting states, most humans will breathe preferentially through the nose.

During exercise, minute ventilation rapidly increases, and may reach up to 40 litres per minute. The dominant breathing route rapidly switches from the nose to the mouth, with its obvious advantages of increased diameter and reduced resistance to airflow.[2] The nasal airway continues to contribute, albeit at a reduced proportion, and sympathetic drive leads to vasoconstriction of the nasal capacitance vessels, shrinking back of the mucosa and reduced resistance to nasal airflow.[3] These changes are evident after as little as 5 minutes of light exercise. Despite these changes, the nasal airway contributes as little as 10 per cent of the overall minute ventilation at maximal exercise intensity.[4] The relative unimportance of the nasal airway can be demonstrated by the disappointing results of attempts to increase aerobic capacity by reducing nasal resistance through the use of 'nasal dilator strips'[5–7] or a pharmacological decongestant.[8] Equally, there is no hindrance to maximal aerobic performance when wearing an occlusive nose clip.[9] The nasal airway, it seems, is not a limiting factor in acute exercise.

Mucosal function and immunity

Innate immune strategies within the nose include physical barriers (cilia, mucus and epithelium), both cellular

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(neutrophils and macrophages) and humoral (secretions containing lactoferrin and lysozyme). Cells of the adaptive immune system also reside within the nasal mucosa, with large numbers of dendritic cells co-existing as antigen-presenting cells. Secretions containing immunoglobulins and antimicrobial proteins are thought to be a key foundation of nasal mucosal immunity.

Exercise-induced changes in nasal secretions during exercise have had surprisingly little attention, far less than that given to salivary markers of immune function. Early studies confirmed that the volume of nasal secretions produced during submaximal exercise increases.[10,11] There is a wealth of evidence supporting acute and chronic reductions in salivary immunoglobulin A and antimicrobial protein levels during maximal exercise and heavy training periods.[12–14] By extrapolation, it might be expected that nasal secretions would follow a similar pattern. However, further investigation into the adaptations in nasal mucosal immunity in response to exercise is required in order to make robust conclusions.

Exercise-related nasal dysfunction

The nose may seem unlikely to be a limiting factor in a single maximal exercise effort, but nasal health may impact the athlete outside of the acute exercise environment. It is well recognised that sufferers of sinonasal disease have reduced scores of sleep quality, mood and overall quality of life compared to unaffected peers.[15,16] Upper respiratory tract infections are also an important source of morbidity in the athlete as they are the most common illness encountered in this population. There is good reason to suspect, therefore, that nasal dysfunction may have significant secondary effects on an athlete's health and performance.

Prevalence of rhinitis in athletes

There have been a number of studies investigating the prevalence of rhinitis in athletes, with observed rates ranging from 15 to 47 per cent.[17–19] The rates vary with the diagnostic criteria and athlete population. One well-conducted study of German elite athletes demonstrated significantly higher rates of rhinitis in athletes than in the general population (25.4 *vs* 16.9 per cent, $p < 0.05$).[20] Other large-scale studies conducted on Polish,[21] Australian[22] and Finnish[23] Olympic athletes support a similar prevalence.

Different athlete groups have differing risk profiles for rhinitis. There is a recognised subtype of vasomotor rhinitis known as 'skier's nose', and up to 48 per cent of winter sports competitors may experience cold air related symptoms such as rhinorrhoea and congestion.[24] Swimmers also have a uniquely pro-rhinitis exercise environment – chlorine use in pools may contribute to or exacerbate nasal dysfunction. The frequency of rhinitis in swimmers is comparable to that of land-based athletes,[25] but there are subtle differences in presentation. Cytologically, swimmers are more likely to demonstrate irritative rather than allergic rhinitis.[26] Clinically, swimmers' rhinitis also presents differently: whereas runners tend to see a transient improvement in symptoms and a reduction in nasal airway resistance during exercise, swimmers tend to report a worsening of symptoms and a paradoxical increase in nasal airway resistance.[27]

Rhinitis and asthma in athletes

The last decade has seen deepening understanding of the functional complementarity of the upper and lower airways as a single 'unified airway'. As such, rhinitis and asthma frequently co-exist, with over 80 per cent of asthmatics suffering from rhinitis and 10–40 per cent of rhinitics suffering from asthma.[28] Extensive and repeated athlete studies have returned an increased prevalence of asthma, with participants in endurance sports reporting the highest rates of asthma.[29–31]

The last decade has seen widespread acceptance of two distinct asthma phenotypes: exercise-induced asthma and exercise-induced bronchoconstriction. The distinction lies in background respiratory function. Exercise-induced asthma implies a background of airway hyper-responsiveness that may be exacerbated by exercise. In contrast, exercise-induced bronchoconstriction implies airway hyper-responsiveness that is solely triggered by exercise. One postulated mechanism for exercise-induced bronchoconstriction is airway drying in response to hyperpnoea, with dehydration of airway epithelium leading to injury that can be demonstrated by the increased shedding of epithelial cells and the release of inflammatory mediators.[32,33]

Common sense might suggest that athletes will follow a similar pathophysiological pattern to the general population, but the confirmation of rhinitis co-existing with exercise-induced asthma and/or exercise-induced bronchoconstriction remains largely uninvestigated.

Upper respiratory tract infections in athletes

Upper respiratory tract infections are an enormous burden to athletes. They are the most frequent reason for presentation to sports physicians,[34] and are the most common medical problems encountered at both Winter and Summer Olympics.[35,36] The J-curve of mucosal immunity, which proposes a depression in immunity with intensive exercise, has been suggested as a model to explain the increased frequency of upper respiratory tract infections in athletes following competitions.[37] This has been supported with clinical observations following extreme endurance events, with participants being up to five times more likely to suffer upper respiratory tract infections following the event than non-participating control subjects.[38,39]

However, studies investigating specific pathogens have failed to identify an infectious agent in as many as 50 per cent of athletes reporting upper respiratory tract infection symptoms.[40,41] This had led to a non-infectious hypothesis which supposes that many of the upper respiratory tract symptoms classically linked with infections (sneezing, blocked or runny nose, and coughing) are secondary to airway epithelial

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injury, cytokine release and mucosal oedema that arise from intense exercise. Athletes with underlying allergic airway disease such as asthma or allergic rhinitis would, in this model, be more likely to suffer with these types of symptoms because of a background chronic inflammatory process. This was elegantly demonstrated in a British study of London marathon competitors, in which competitors' household companions were utilised as the non-running controls.[42] Post-marathon, runners suffered from more upper respiratory tract infection symptoms than the non-runners, but there was a low proportion (less than 25 per cent) of households where both the runner and non-runner control were affected, undermining an infectious hypothesis. Rather, there was a strong association between allergic and upper respiratory tract infection symptoms in the runner group. Allergic rhinitis may therefore actually predispose the athlete to the symptoms of upper respiratory tract infection, which has the associated cost to training and wellbeing. Further study is of course required, but it seems possible that prophylactic treatment of rhinitis could yield exciting developments in the reduction of post-exercise upper respiratory tract infection symptoms in athletes.

Conclusion

Nasal health is clearly of key importance to the athlete. While not a limiting factor in a single exercise effort, the effects of nasal dysfunction can have repercussions in the post-exercise recovery period. Nasal dysfunction is associated with worse sleep quality, mood scores and quality of life. Furthermore, it is linked with the development of asthma and may increase susceptibility to upper respiratory tract symptoms. On the basis of the evidence presented, we recommend that both athletes and sports physicians remain mindful of the importance of maintaining nasal health.

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