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# **The respiratory Health of Young Swimmers**

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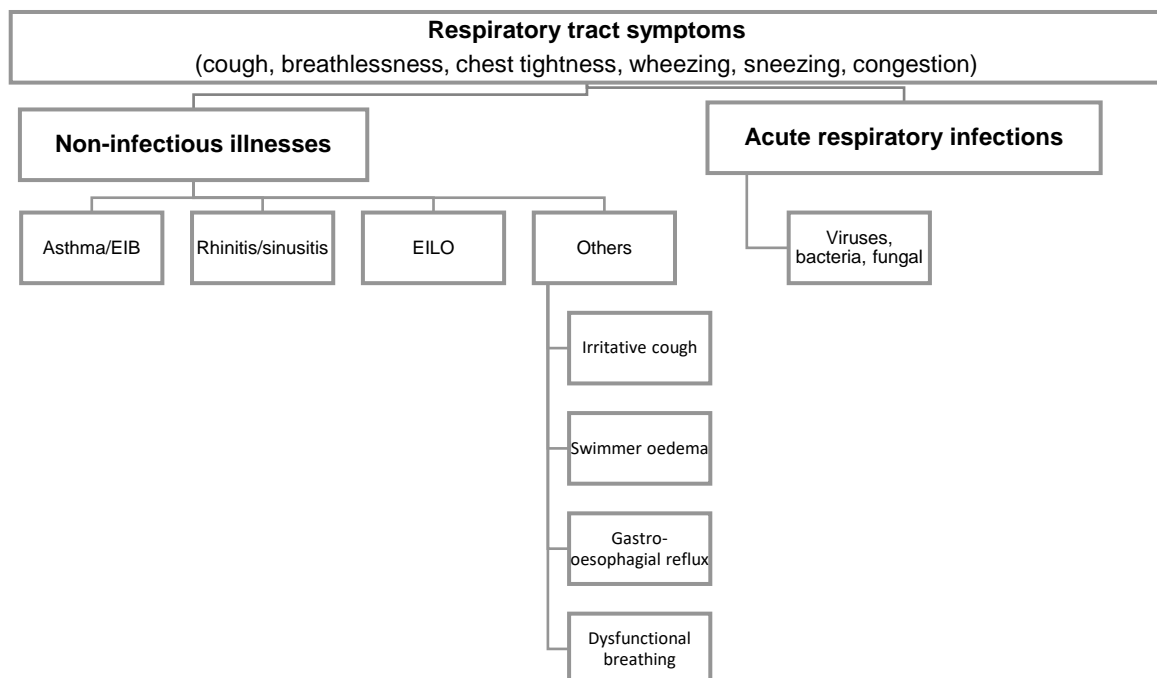
## **Introduction**

The global benefits of regular swimming for mental and physical health are well recognized with numerous desirable impacts. Cross-sectional data reveals that swimmers often have better lung function than non-asthmatic age-matched controls and regular swimming has also been shown to improve lung capacity more than would be expected and/or projected in adolescents (Silvestri et al. 2013).

It is also, however, now recognized that competitive swimmers are at heightened risk of developing both respiratory symptoms and pulmonary disease and this is associated with time spent in indoor pools. Specifically, it appears the exposure to the chlorine disinfection products, often utilised in indoor swimming pool environments, tallied with a high intensity and frequent training load, is thought to contribute to the development of respiratory 'dysfunction'. Indeed, the vast majority of swimmers still train in chlorinated-disinfected pools and there is a clear association between symptom development and severity of the noxious odour of chlorine (Potts 1994, Deitmer et al. 1990). The severity of the odour of chlorine is important as poor pool ventilation leads to more swimmers suffering from severe respiratory symptoms (Levesque et al. 2006, 2015, Potts 2014). In contrast, it appears that non chlorinated-disinfected pools, but also probably outdoor pools, provoke far fewer respiratory symptoms (Gomà et al. 2017, Fernandez-Luna et al. 2015), and that occurrence of such symptoms decreases after high-quality maintenance of the pool environment (Simon-Rigaud et al. 1997).

Many young swimmers (i.e. age <16 years old) appear to develop respiratory dysfunction and indeed recognizing and accurately diagnosing respiratory problems in this group of athletes is vital to maintain both their health and optimal performance.

The present chapter provides a summary of evidence for respiratory illness and describes the type of conditions often encountered in the young swimmer (Figure 1). A few less common conditions (e.g. swimming-induced pulmonary edema) which may provoke specific symptoms are not covered in the present chapter but are included in the figure for information.



**Figure 1:** The main diagnosis for respiratory symptoms in swimmers. EIB : exercise-induced bronchoconstriction ; EILO : exercise-induced laryngeal obstruction

## Respiratory Tract Symptoms in Swimmers

Respiratory tract symptoms are highly prevalent in young competitive swimmers from regional to international competitive level. Their development is related to age, sex, level of competition, and amount of time spent swimming (Potts 1994); i.e. the more a swimmer trains, the higher

the likelihood of being affected during or after training sessions. A greater number of respiratory symptoms are encountered in older than younger swimmers and female swimmers are more likely to experience coughing, congestion or have difficulties breathing (Potts 1994). This may be because female swimmers have smaller lungs and airway (Thurleck 1982).

Symptoms such as cough, congestion, wheeze, sneeze, chest tightness, difficulty breathing, but also health-related symptoms such as sore throat and eyes, headaches or ear infections, are more often reported in swimmers than in other age-matched athletes, such as soccer players (Levesque et al. 2006, Potts 2014). Sometimes the severity of the symptoms is such that swimmers have to stop training (Potts 1994). In general, a few days or hours away from chlorine-disinfected pools are enough to ensure respiratory symptoms regress (Potts 2014, Helenius and Haahtela 2000, Beretta et al. 2011).

In all cases, it is critical to identify the cause of young swimmer's symptoms, which may otherwise lead to respiratory impairment. This is vital to protect the health of swimmers, but also to avoid performance impairment.

The causes of swimming related may be cumulative and symptoms may relate to several pathological conditions. Therefore, in a case where one cannot address the problem, they would be advised to consult a pulmonologist with expertise in this field.

The main causes of respiratory symptoms are likely infections, chlorine or exercise-induced airway inflammation, allergic disease, asthma or exercise-induced bronchoconstriction (EIB), and exercise-induced laryngeal obstruction (EILO). The term EIB is used to describe an acute transient airway narrowing provoked by exercise. It is observed in individuals with or without asthma and is very frequent in highly-trained endurance sport athletes (Parsons 2014).

## **Acute Respiratory Tract Illness**

In general, upper respiratory symptoms represent 35 to 65% of all consultations for illnesses to a sports medicine physician (Gleeson and Pyne 2016) and are generally assumed to be caused by infections, i.e. common respiratory viruses, viral reactivation (often Epstein-Barr virus reactivation). In fact, in the majority of cases, no acute infective pathogen is identified, and many acute respiratory presentations may actually represent allergy +/- upper airway inflammation. It is rare to identify bacterial or fungal infection and although techniques to identify infection are rapidly evolving (Valtonen et al. 2019), there is still a case for other causes of respiratory illness to be considered.

Respiratory illnesses may prevent training and impair performance at a given time, but when recurrent they also have a significant impact on annual performance and swimmer's psychological and physiological health (Pyne et al. 2005). The transient exercise-induced immune suppression after periods of strenuous training, the physiological and psychosocial stress observed in daily life, or around major events, but also mineral or vitamin D deficiencies have been implicated in the susceptibility of competitive athletes to common infections (Umarov et al. 2019, Prien et al. 2017, Gleeson and Pyne 2016). The factors underpinning an individual's susceptibility to infections are still to be fully established, as not all swimmers are prone to respiratory illnesses to genetics are still to be studied, as not all swimmers are prone to respiratory illnesses (Gleeson and Pyne 2016).

Another specific consideration concerns open water swimmers, who by virtue of their sporting discipline practice and compete in lakes, rivers or seas. This is becoming more popular in the youth. The risk of acute respiratory infections is high in open water recreational swimmers/bathers, especially in crowded waters (Mannocci et al. 2016). However, due to a supervised water quality during official competitive event, international open water competitive swimmers do not seem to be more affected by respiratory illnesses than other swimmers (Prien

et al. 2017). Swimmers and/or their support teams should check water quality where they train and compete.

## **Non-Infectious Respiratory Illnesses**

As respiratory symptoms may be of non-infectious origin, it is advisable to eliminate other possible causes of symptoms and / or confirm the infection with clinical tests (Gleeson and Pyne 2016).

Allergies as a cause of respiratory symptoms are often misdiagnosed and under-managed in athletes, as it is the case for non-infectious non allergic but chlorine-induced rhinitis that are very frequent in swimmers (Gleeson and Pyne 2016, Bougault et al. 2010, Gelardi et al. 2010). Moreover, not only allergy but also asthma is commonly diagnosed in elite athletes experiencing recurrent upper respiratory tract infections (URTI). Viruses may exacerbate both diseases, as observed in asthmatic children (Abe et al. 2019). These observations highlight the need for scientists to study in more depth the causes and interactions of the upper and lower airway and how allergy may predispose individuals to infectious causes of respiratory tract illness. While non-infectious respiratory illnesses such as allergies +/- asthma are better understood, the reasons for their development in swimmers remain unclear, with very little known in young swimmers.

## **Management of Infective and Non-infective Respiratory Symptoms**

Several easy measures in everyday life can be implemented to reduce the incidence of URTI in swimmers. Their management should be based on the prevention of infections through nutritional interventions (see chapter 17) and the respect of simple hygienic recommendations rather than using therapeutic interventions (Gleeson and Pyne 2016). For example, the incidence and severity of upper respiratory tract symptoms has been shown to reduce after taking some strains of probiotic supplementation during one month or more, or when

supplemented with antioxidant, especially vitamin D or  $\beta$ -Glucan (Jesenah et al. 2017, Gleeson and Pyne 2016). Occasionally, it might be necessary to transiently decrease training load during the supplementation (see chapter 9) to improve the immune function of the athlete who suffers from recurrent symptoms (Gleeson and Pyne 2016).

The use of topical anti-inflammatory nasal spray may also help to decrease the symptoms severity in some athletes, whether the cause is infectious or not (Gleeson and Pyne 2016). But nasal spray does not reduce the frequency of symptoms' occurrence. Saline irrigation, before and/or after swimming may also be an alternative, as it is used for allergic rhinitis (Head et al. 2018), even if no scientific evidence is available at that time. Hygiene measures, and especially (1) avoiding contact with persons showing signs of upper airway infections, particularly while undertaking intensive training schedules and before major competitions, (2) avoiding the sharing of bottles, and (3) regularly washing hands, are efficient measures to reduce illnesses in athletes (Handstad et al. 2011). Finally, when athletes are members of teams housed together, any team member / staff member who is developing a respiratory tract infection should be isolated, as far as is practical.

### **Allergic Sensitization / Atopy and Allergies**

Atopy is a genetic predisposition to produce specific Immunoglobulin E (IgE) after exposure to allergens (Teixeira et al. 2018). An atopic status is diagnosed by the presence of either specific IgE antibodies in blood serum or the occurrence of at least one sensitization to skin prick tests using common airborne allergens (animal danders, house dust mites, mixed trees and grasses, pollens and moulds). Atopy may or may not be accompanied with the symptoms associated with allergic disease. Allergies, by contrast, are a hypersensitivity reaction initiated by immunological mechanisms (Teixeira et al. 2018).

In elite swimmers, the frequency of sensitisation to various aeroallergens is increased compared with age-matched non-athletes (Helenius et al. 2000, 1998, Zwick et al. 1990), but is similar to other endurance sport athletes. A swimmer who frequently attends chlorinated swimming-pools during childhood is more at risk to develop further allergic respiratory disease, generally asthma or rhinitis, in their adulthood (Voisin et al. 2014, Bernard 2007). Both chlorine by-products and repeated intense training sessions have been linked in the development of allergies in swimmers. Both may lead to transient damage of the airway epithelium, which then ease the body's intake of aeroallergens and increase the risk of allergic manifestations (Tufvesson et al. 2013, Bernard 2007, Kohlhammer et al. 2006).

The main manifestations of allergy in swimmers are rhinitis and asthma but also conjunctivitis and atopic dermatitis (Potts 1994, Zwick et al. 1990). Allergic diseases are generally under-diagnosed and under-treated in competitive athletes, including in competitive swimmers, and may have significant consequences for performance (Katelaris et al. 2000, Komarow and Postolache 2005). In case of recurrent respiratory symptoms, it is therefore important that skin prick tests +/- blood testing to specific IgE is undertaken to identify any possible responsible allergenic sensitisation. Ant identified allergies should be properly treated and not ignored.

### **Swimmers' Rhinitis and Sinusitis**

Troublesome nasal symptoms in swimmers arise either from an allergic or non-allergic origin (Gelardi et al. 2010, Bougault et al. 2010, Deitmer and Scheffler 1990). Several factors seem to be involved in the development rhino-sinusitis symptoms in swimmers, specifically cooling of the skin when entering the pool, entry of water in the nasal cavity, and the presence of chlorine in the atmosphere and water (Gelardi et al. 2010, Deitmer and Scheffler 1990). Inflammation (neutrophils predominantly) may arise in the upper airway due to the direct irritating effect of chlorinated water; it has been reported in many swimmers suffering from non-allergic rhinitis



with symptoms disappearing completely when they wear a nose clip (Bernard et al. 2015, Gelardi et al. 2012). Exposure to chlorinated water also increases inflammation of those suffering from rhinitis of allergic origin (Deitmer and Scheffler 1990).

### **Asthma / Exercise-Induced Bronchoconstriction**

Swimming is often considered to be the ‘sport of choice’ for asthmatics. It is often recommended to young asthmatics given the warm and humid atmosphere and is thought to be a less asthmogenic activity than other endurance sports (Bar-Yishay. et al. 1982, Bar-Or and Inbar 1992). Other reasons to recommend swimming include the horizontal position and the peculiar respiratory patterns adopted in swimming, both recognised as beneficial for asthmatics (Bar-Or and Inbar 1992).

Competitive swimmers with well-controlled asthma perform as well as their peers, up to the highest level (Mountjoy et al. 2015b). At the Olympic level, asthmatic athletes even outperform their non-asthmatic counterparts (McKenzie and Fitch 2011).

Some asthmatics may be sensitive to chlorine, which can trigger asthma attacks, either regularly or from time to time. This will depend on how well their asthma is controlled and the level of trichloramines in the air of the swimming pool (“chlorine odour”). For each asthmatic, an individual management plan should thus be put in place and regularly reviewed. The prevalence of asthma is high in highly-trained competitive swimmers (Mountjoy et al. 2015a). Therefore, recurrent breathlessness, wheezing, cough, or chest tightness after swimming should signal possible undiagnosed asthma in children and adolescents, even in those without childhood asthma or allergies.

Some swimmers, particularly young swimmers, may perform running-based activities alongside their swimming training and care should be taken to record respiratory symptoms after these activities as running is recognised as more asthmogenic than swimming. For

example, during a search protocol (Bougault V., unpublished data), a national swimmer was diagnosed with an airway hyperresponsiveness (a characteristic of asthma diagnosed using the methacholine challenge). She reported no respiratory symptoms during efforts. After taking the right medication, she realised that she had breathlessness following running, that she originally attributed to the fact that she was a poor runner. With more insight, she probably experienced exercise-induced bronchoconstriction (“asthma”), following running but not swimming. This is more likely to happen after several years of training in swimmers competing for many years, and therefore in early adulthood. Some respiratory symptoms and/or characteristics of asthma may develop during a swimming career, and a regular follow-up of airway function and responsiveness would be advisable, even in those without known respiratory pathology or symptoms. Asthma may remain under-diagnosed in swimmers. Respiratory symptoms are also often diagnosed as asthma where they may be an expression of another condition such as laryngeal obstruction, and there may finally be a combination of both conditions, acting to confound diagnosis and treatment strategy.

### **Management of Allergic Disease and Asthma**

Swimmers with known allergies/rhinitis/asthma should avoid training in environments where levels of airborne allergens or chloramines are high. They should also take their medication. A regular visit to their pulmonologist is advisable, especially if there are periods of less well-controlled asthma. For those who never had a diagnosis of such pathology, recurrent respiratory symptoms (as described above) should alert for the possible existence of one of the respiratory conditions presented in this chapter. When an allergy or asthma is suspected, skin prick tests should be performed in addition to a rest spirometry, and the reversibility test using a bronchodilator may be tested. This test is very simple to perform that may indicate an airway obstruction at rest, at the time of testing. After an initial spirometry test, the athlete is given 200 mg of a bronchodilator and, at least ten minutes later, a second spirometry test is performed.

An airway obstruction may be diagnosed depending on the decrease in respiratory flow parameters. To diagnose an exercise-induced asthma, an exercise challenge, eucapnic voluntary hyperpnea challenge or methacholine test may be performed, even if a negative result (i.e. no effect found) does not preclude its existence (Fitch et al. 2008). The reader interested in the management of asthma and bronchial provocation test in athletes, should consult a short guide published in 2008 (Fitch et al. 2008).

### **Exercise-Induced Laryngeal Obstruction (EILO)**

It is now recognized that many young athletes with dyspnoea, wheezing and/or coughing may actually be developing respiratory distress due to a transient, excessive closure of the laryngeal inlet (Griffin et al. 2019). This exercise associated laryngeal obstruction appears to be highly prevalent in adolescents with one study estimating that approximately 5% of all Scandinavian adolescents may suffer with this condition (Johansson et al. 2015) and in some series was nearly as common as asthma as a cause of ‘unexplained’ breathing difficulties in athletes (Nielsen et al. 2013).

Athletes with EILO typically report difficulty in breathing at maximum or near maximal exercise intensity and may develop a commensurate wheeze on the inspiratory phase of the respiratory cycle, also termed stridor. Typically, symptoms of EILO resolve fairly rapidly after exercise cessation (i.e. <10 minutes). Given the nature of the wheeze and distress caused by EILO, it may be the coach or a family member who first highlights the fact that these symptoms are atypical, i.e. not those of asthma or EIB. Likewise, when assessing a swimmer with potential EILO, it can be useful to ask for a video recording of the breathing difficulties on poolside.

	<b>Exercise-induced Obstruction (EILO)</b>	<b>Laryngeal</b>	<b>Exercise-induced Bronchoconstriction (EIB)</b>
<b>Onset</b>	<ul style="list-style-type: none"> <li>• Sudden onset within seconds during high intensity exercise.</li> <li>• Warm-up does not affect symptom severity</li> </ul>		<ul style="list-style-type: none"> <li>• Gradual onset within five minutes of terminating exercise</li> <li>• Warm-up can attenuate symptom severity</li> </ul>
<b>Symptom localisation</b>	<ul style="list-style-type: none"> <li>• Throat or upper chest</li> </ul>		<ul style="list-style-type: none"> <li>• Chest</li> </ul>
<b>Symptom quality</b>	<ul style="list-style-type: none"> <li>• Inspiratory only</li> <li>• High-pitch or wheezing sound on inspiration</li> <li>• Throat tightness</li> <li>• Cough during exercise</li> </ul>		<ul style="list-style-type: none"> <li>• Inspiratory and expiratory</li> <li>• Chest tightness</li> <li>• Cough following exercise cessation</li> </ul>
<b>Post exercise duration</b>	Under ten minutes		Up to thirty minutes
<b>Response to inhalers</b>	Little-to-none		Symptom resolution

The gold standard means for diagnosing EILO is the continuous laryngoscopy during exercise (CLE) test. This test involves the placement of a small flexible laryngoscope in the post nasopharynx and this then permits continuous visualization of the laryngeal aperture during exercise, to detect and characterise EILO. The CLE test is most commonly performed on a treadmill or cycle-ergometer, although can be successfully undertaken in the pool environment (Walsted et al. 2017).

The reason it is important to detect EILO in young swimmers is that it (i) helps provide targeted breathing techniques to optimise breathing control and performance, and (ii) avoids inappropriate use and escalation of asthma therapy. For further information, the reader is encouraged to review the work of Griffin et al. (Griffin et al. 2019).

## **Conclusion**

Competitive swimmers are very commonly affected by various respiratory diseases, which can impair their training, performance, and quality of life. Easy measures may be taken in the daily life and training routines of the young athletes, such as a reduction in training load during URTI episodes or some nutritional adjustments (see Chapter 17). In the case of recurrent upper or

lower airway respiratory symptoms, it is recommended that any affected young swimmer should consult a pulmonologist with expertise in the field of exercise and respiratory health.

## **Recommendations**

- Pool air quality should be checked and exposure to high levels of chlorinated by-product minimised
- Open water swimming venues should ensure water quality is maintained
- Objective testing should be used to establish the cause of any young swimmer's respiratory symptoms
- Identify and confirm allergy and provide advice and treatment
- Several simple interventions act to help reduce the chance of infection

## **References**

Abe N, Yasudo H, Fukano R, Nakamura T, Okada S, Wakiguchi H, Okazaki F, Shirabe K, Toda S, Okamoto R, Ouchi K, Ohga S, Hasegawa S. Multi-season analyses of causative pathogens in children hospitalized with asthma exacerbation. *Pediatr Allergy Immunol* 2019. doi: 10.1111/pai.13102.

Bar-Or O, Inbar O. Swimming and asthma. *Sports Med* 1992;16:397-405

Bar-Yishay E, Gur I, Inbar O, Neuman I, Dlin RA, Godfrey S. Differences between swimming and running as stimuli for exercise-induced asthma. *Eur J Appl Physiol Occup Physiol* 1982;48(3):387-97

Bernard A. Chlorination products: emerging links with allergic diseases. *Curr Med Chem* 2007;14(16):1771-82

Bernard A, Carbonnelle S, Michel O, Higuët S, De Burbure C, Buchet JP, Hermans C, Dumont X, Doyle I. Lung hyperpermeability and asthma prevalence in schoolchildren: unexpected

associations with the attendance at indoor chlorinated swimming pools. *Occup Environ Med* 2003;60(6):385-94

Beretta S, Vivaldo T, Morelli M, Carlucci P, Zuccotti GV. Swimming pool-induced asthma. *J Investig Allergol Clin Immunol* 2011;21(3):240-1

Bernard A, Nickmilder, M, Dumont X. Chlorinated pool attendance, airway epithelium defects and the risks of allergic diseases in adolescents: Interrelationships revealed by circulating biomarkers. *Environ Res* 2015;140:119-26

Bougault V, Turmel J, Boulet LP. Effect of intense swimming training on rhinitis in high-level competitive swimmers. *Clin Exp Allergy* 2010 ;40(8) :1238-46

Deitmer T, Scheffler R. Nasal physiology in swimmers and swimmers' sinusitis. *Acta Otolaryngol* 1990;110:286-91

Fernandez-Luna A, Burillo P, Felipe JL, del Corral J, García-Unanue J, Gallardo L. Perceived health problems in swimmers according to the chemical treatment of water in swimming pools. *Eur J Sport Sci* 2016;16(2):256-60

Fitch KD, Sue-Chu M, Anderson SD, Boulet LP, Hancox RJ, McKenzie DC, Backer V, Rundell KW, Alonso JM, Kippelen P, Cummiskey JM, Garnier A, Ljungqvist A. Asthma and the elite athlete: summary of the International Olympic Committee's consensus conference, Lausanne, Switzerland, January 22-24, 2008. *J Allergy Clin Immunol* 2008;122(2):254-60

Gelardi M, Ventura MT, Fiorella R, Fiorella ML, Russo C, Candreva T, Carretta A, Passalacqua G. Allergic and non-allergic rhinitis in swimmers: clinical and cytological aspects. *Br J Sports Med* 2012;46(1):54-8

Gleeson M, Pyne DB. Respiratory inflammation and infections in high-performance athletes. *Immunol Cell Biol* 2016 ;94 :124-31

Gomà A, de Lluís R, Roca-Ferrer J, Lafuente J, Picado C. Respiratory, ocular and skin health in recreational and competitive swimmers: Beneficial effect of a new method to reduce chlorine oxidant derivatives. *Environ Res* 2017;152:315-21

Griffin SA, Walsted ES, Hull JH. Infographic. The breathless athlete: EILO. *Br J Sports Med* 2019;53(10):616-7

Hanstad DV, Rønsen O, Andersen SS, Steffen K, Engebretsen L. Fit for the fight? Illnesses in the Norwegian team in the Vancouver Olympic Games. *Br J Sports Med* 2011;45(7):571-5

Head K, Snidvongs K, Glew S, Scadding G, Schilder AG, Philpott C, Hopkins C. Saline irrigation for allergic rhinitis. *Cochrane Database Syst Rev* 2018;6:CD012597

Helenius I, Haahtela T. Allergy and asthma in elite summer sport athletes. *J Allergy Clin Immunol* 2000;106(3):444-52

Helenius IJ, Tikkanen HO, Sarna S, Haahtela T. Asthma and increased bronchial responsiveness in elite athletes: atopy and sport event as risk factors. *J Allergy Clin Immunol*. 1998;101(5):646-52

Hellard P, Avalos M, Guimaraes F, Toussaint JF, Pyne DB. Training-related risk of common illnesses in elite swimmers over a 4-yr period. *Med Sci Sports Exerc* 2015;47(7):1416-25

Inbar O, Dotan R, Dlin RA, Neuman RI, Bar-Or O. Breathing dry or humid air and exercise-induced asthma during swimming. *Eur J Appl Physiol Occup Physiol* 1980;44(1):43-50

Jesenak M, Urbancikova I, Banovcin P. Respiratory Tract Infections and the Role of Biologically Active Polysaccharides in Their Management and Prevention. *Nutrients* 2017;9(7). pii: E779

Johansson H, Norlander K, Berglund L, Janson C, Malinovschi A, Nordvall L, Nordang L, Emtner M. Prevalence of exercise-induced bronchoconstriction and exercise-induced laryngeal obstruction in a general adolescent population. *Thorax* 2015;70(1):57-63

Katellaris CH, Carrozzi FM, Burke TV, Byth K. A springtime olympics demands special consideration for allergic athletes. *J Allergy Clin Immunol* 2000;106(2):260-6

Kohlhammer Y, Döring A, Schäfer T, Wichmann HE, Heinrich J; KORA Study Group. Swimming pool attendance and hay fever rates later in life. *Allergy* 2006;61(11):1305-9

Komarow HD, Postolache TT. Seasonal allergy and seasonal decrements in athletic performance. *Clin Sports Med* 2005;24(2):e35-50

Lévesque B, Vézina L, Gauvin D, Leroux P. Investigation of Air Quality Problems in an Indoor Swimming Pool: A Case Study. *Ann Occup Hyg* 2015;59(8):1085-9

Lévesque B, Duchesne JF, Gingras S, Lavoie R, Prud'Homme D, Bernard E, Boulet LP, Ernst P. The determinants of prevalence of health complaints among young competitive swimmers. *Int Arch Occup Environ Health* 2006;80(1):32-9

McKenzie DC, Fitch KD. The asthmatic athlete: inhaled Beta-2 agonists, sport performance, and doping. *Clin J Sport Med* 2011;21(1):46-50

Mannocci A, La Torre G, Spagnoli A, Solimini AG, Palazzo C, De Giusti M. Is swimming in recreational water associated with the occurrence of respiratory illness? A systematic review and meta-analysis. *J Water Health* 2016;14(4):590-9

Maruyama-Nagao A, Sakuraba K, Suzuki Y. Seasonal variations in vitamin D status in indoor and outdoor female athletes. *Biomed Rep* 2016;5(1):113-7

Mountjoy M, Fitch K, Boulet LP, Bougault V, van Mechelen W, Verhagen E. Prevalence and characteristics of asthma in the aquatic disciplines. *J Allergy Clin Immunol* 2015a;136(3):588-94

Mountjoy M, Junge A, Benjamin S, Boyd K, Diop M, Gerrard D, van den Hoogenband CR, Marks S, Martinez-Ruiz E, Miller J, Nanousis K, Shahpar FM, Veloso J, van Mechelen W, Verhagen E. Competing with injuries: injuries prior to and during the 15th FINA World Championships 2013 (aquatics). *Br J Sports Med* 2015b;49(1):37-43



Nielsen EW, Hull JH, Backer V. High prevalence of exercise-induced laryngeal obstruction in athletes. *Med Sci Sports Exerc* 2013;45(11):2030-5

Parsons JP. Exercise-induced bronchoconstriction. *Otolaryngol Clin North Am* 2014;47(1):119-26

Potts JE. Adverse respiratory health effects of competitive swimming: the prevalence of symptoms, illness, and bronchial responsiveness to methacholine and exercise [dissertation]. Vancouver (BC): University of British Columbia, 1994

Prien A, Mountjoy M, Miller J, Boyd K, van den Hoogenband C, Gerrard D, Cherif MY, Lu Y, Nanousis K, Ortiz Liscano EI, Shahpar FM, Junge A. Injury and illness in aquatic sport: how high is the risk? A comparison of results from three FINA World Championships. *Br J Sports Med* 2017;51(4):277-82

Pyne DB, Hopkins WG, Batterham AM, Gleeson M, Fricker AP. Characterising the individual performance responses to mild illness in international swimmers. *Br J Sports Med* 2005;39:752-6

Silvestri M, Crimi E, Oliva S, Senarega D, Tosca MA, Rossi GA, Brusasco V. Pulmonary function and airway responsiveness in young competitive swimmers. *Pediatr Pulmonol* 2013;48:74-80

Simon-Rigaud ML, Eechout C, Bourdin H, Mougin F, Henry Y, Kantelip JP. Bronchial hyperreactivity and swimming: influence of training in a chlorinated swimming-pool [in French]. *Sci Sports* 1997; 12(2):142-7 [French]

Teixeira RN, Leite GDS, Bonini M, Gorjão R, Agondi RC, Kokron CM, Carvalho CRF. [Atopy in Elite Endurance Athletes](#). *Clin J Sport Med* 2018;28(3):268-71

Thurleck WM. Postnatal human growth. *Thorax* 1982;37(8):564-71

Tufvesson E, Svensson H, Ankerst J, Bjermer L. Increase of club cell (Clara) protein (CC16) in plasma and urine after exercise challenge in asthmatics and healthy controls, and correlations to exhaled breath temperature and exhaled nitric oxide. *Respir Med* 2013;107(11):1675-81

Umarov J, Kerimov F, Toychiev A, Davis N, Osipova S. Association the 25(OH) Vitamin D status with upper respiratory tract infections morbidity in water sports elite athletes. *J Sports Med Phys Fitness* 2019 doi: 10.23736/S0022-4707.19.09834-7

Valtonen M, Waris M, Vuorinen T, Eerola E, Hakanen AJ, Mjosund K, Grönroos W, Heinonen OJ, Ruuskanen O. Common cold in Team Finland during 2018 Winter Olympic Games (PyeongChang): epidemiology, diagnosis including molecular point-of-care testing (POCT) and treatment. *Br J Sports Med* 2019;53(17):1093-98

Voisin C, Sardella A, Bernard A. Risks of new-onset allergic sensitization and airway inflammation after early age swimming in chlorinated pools. *Int J Hyg Environ Health* 2014;217(1):38-45

Walsted ES, Swanton LL, van van Someren K, Morris TE, Furber M, Backer V, Hull JH. Laryngoscopy during swimming: A novel diagnostic technique to characterize swimming-induced laryngeal obstruction. *Laryngoscope* 2017;127(10):2298-2301

Zwick H, Popp W, Budik G, Wanke T, Rauscher H. Increased sensitization to aeroallergens in competitive swimmers. *Lung* 1990;168 (2): 111-5