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The Impact of Swimming Training on the Course and Symptoms of Bronchial Asthma and Respiratory System Function: A Literature Review

Anita Ptak, Michał Szyc

Anita Ptak M.D.
ORCID https://orcid.org/0009-0001-1237-7476
Provincial Specialist Hospital named after the Blessed Virgin Mary
Ul. Bialska 104/118, 42-200 Częstochowa, Poland
e-mail: anita98ptak@gmail.com

Michał Szyc M.D.- corresponding author
ORCID https://orcid.org/0009-0002-4478-6618
Provincial Specialist Hospital named after the Blessed Virgin Mary
Ul. Bialska 104/118, 42-200 Częstochowa, Poland
e-mail: lek.szyc@gmail.com

Abstract:
Introduction: Bronchial asthma is one of the most common inflammatory diseases among adults and children. It is characterized by the occurrence of bronchial obstruction, which is manifested, for instance, by a feeling of shortness of breath, wheezing, a feeling of tightness in the chest, a feeling of squeezing in the chest. In addition to pharmacological treatment, health behavior including sport is of great importance.

In this publication, we will attempt to discuss the effects of swim training on asthma and respiratory system function. We will try to answer the question whether swimming is a safe form of exercise for patients with bronchial asthma.

Material and methods: Review of the specialized literature in the field of pulmonology, guidelines for treatment of bronchial asthma and articles available on PubMed and Google Scholar database searching by the keywords

Aim of the study: The aim of this publication is to review the available literature to answer the question of whether swimming training is a suitable form of exercise for asthmatic patients and what effect it has on respiratory function

Conclusions: The treatment of bronchial asthma is based on the pharmacological treatment. In addition to medications, non-pharmacological methods and health behaviours are important. Appropriate physical activity for people with asthma may include swimming training, which has a beneficial effect on lung function and asthma symptoms management, especially in the paediatric population. There are studies that suggest that swimming carries a lower risk of causing bronchospasm than other sport activities, however, there are inconclusive reports on the effect of attending chlorinated swimming pools on the development of asthma and allergies. Studies on competitive and elite swimmers show that intensive swimming training, especially in chlorinated pools, can induce bronchial hyperresponsiveness and the risk of developing asthma, but this requires further research.

Keywords: asthma, bronchial asthma, swimming, asthma and swimming, asthma and swimming pool, asthma and chlorine

Introduction:

Asthma as a disease in brief

Asthma is a heterogeneous chronic disease characterised by persistent inflammation in the airways. It can occur at any age. It causes narrowing of the bronchial lumen due to smooth muscle spasm, associated mucosal oedema and increased sputum production in the airway lumen. This results in restricted flow in the lower airways. On physical examination, this is manifested by the presence of wheezing and auscultatory murmurs (in severe cases, the so-called ‘silent chest’ symptom may be present), significant respiratory effort, and a decrease in arterial blood saturation. Patients report symptoms such as a feeling of breathlessness, tightness in the chest and coughing. The diagnosis of asthma is made on the basis of symptoms and varying degrees of bronchial obstruction. There are also so-called asthma phenotypes - allergic asthma, non-allergic asthma, adult-onset asthma, asthma with persistent airflow limitation, asthma with obesity, cough variant asthma and cough predominant asthma. There are many factors that can trigger bronchospasm, such as allergens, viral infections, cold air, irritants such as smoke, fragrances, but also exercises. The main therapeutic goals are to achieve good control of disease symptoms, avoid exacerbations of the disease, prevent persistent bronchial obstruction and maintain normal daily activity [1, 2] .

Epidemiological data

According to the Global Initiative for Asthma (GINA) 2024 report, an estimate of 300 million people worldwide suffer from asthma and approximately 1,000 people a day worldwide die from asthma. The highest mortality rates are recorded in low- and middle-income countries [1].

According to Polish data made available by the National Health Fund (NFZ), it is estimated that about 2 million people suffer from asthma in Poland, with the underdiagnosis of asthma in the Polish population being a major problem. In the data presented, the highest number of asthma patients in Europe was in the United Kingdom (data for 2017)-the number of patients per 1,000 people was 83.7 (compared to 49.2 per 1,000 people in Poland) [3].

Pharmacological treatment

We differentiate between controller medication, reliever medication and additional treatments. Asthma-controller medication include inhaled corticosteroids (ICS), long-acting beta2 agonists (LABA), long-acting muscarinic drugs (LAMA) and leukotriene receptor antagonists (LTRA). Reliever drugs, on the other hand, include short-acting beta2 agonists (SABA), formoterol, short-acting muscarinic antagonists (SAMA). Additionally, oral corticosteroids, biologic therapies, antibiotics may be used in exceptional severe cases. For the treatment of asthma, sublingual (SLIT) and subcutaneous (SCIT) immunotherapy may be considered in some cases [2].

Additional non-pharmacological management

In addition to the use of established pharmacological treatment regimens, the importance of physical activity, smoking cessation (active and passive), avoidance of occupational exposure, appropriate diet, weight reduction in overweight and obese patients, avoidance of exposure to allergens and influenza vaccination is emphasised [2]. As physical activity can trigger asthma symptoms, it is important to promote sporting activities to patients that are suitable for them and do not exacerbate the disease. In a meta-analysis, swimming was shown to be associated with a lower risk of exercise-induced bronchoconstriction (EIB) compared to running and cycling. Swimming was found to have a 4-6 times lower risk of inducing EIB than other activities. [4]. In this article, we have reviewed the available scientific research on the effects of swimming on asthma and airway well-being.

Methodology

In order to find relevant source material to write a comprehensive rewiev on the effects of swimming training on asthma patients, we searched PubMed and Google Scholar using key words such as ‘asthma’, ‘bronchial asthma’, ‘swimming’, ‘asthma and swimming’, ‘asthma and swimming pool’, ‘asthma and chlorine’ to select relevant studies. We mainly focused on large meta-analyses and large studies on representative groups. In addition, we used current guidelines on asthma and its treatment to enrich our work.

Swimming training and bronchial asthma

Effect of swimming training on patients with bronchial asthma

The first available papers on asthmatic children and swimming appeared as early as the 1970s [5]. In a study involving children aged 9 to 16 years who were able to swim and trained under a professional coach 5 hours per week for 5 months. The affected children showed an improvement in physical performance (although it was still less than the control group of healthy children) and a statistically significant reduction in the number of asthmatic episodes (including symptoms such as wheezing, coughing and sputum expectoration) compared to before the training. No effect of swim training has been shown to reduce complaints of exercise-induced asthma [5]. A meta-analysis published in 2021 examined the effect of swim training in children up to 18 years of age on lung function - noting significant improvements, particularly in forced expiratory volume in 1 second (FEV1) and forced vital capacity (FVC%), with no clear effect on peak expiratory flow (PEF%) or FEV1 in percentage [6]. A US meta-analysis examined the impact of swimming programmes on asthmatic patients and showed that participants in these programmes had a statistically significant improvement in asthma severity compared to the control group (42.3% improvement), but without significant differences in lung function parameters, such as FEV1, between swimmers and the control group [4]. In Brazil, a study was conducted on 61 children and adolescents with moderate persistent atopic asthma (MPAA) aged 7-18 years, who were divided into two groups-swimmers and a control group. The swimming group trained twice a week for 3 months. A methacholine test was performed on both groups before and after the intervention. The swim group had an increase in PC20 (bronchial hyperreactivity index) from 0.31±0.25 before training to 0.63±0.78 after training ($p = 0.008$), an increase in maximum inspiratory pressure (MIP) from 67. 08±17.13 cm H2O to 79.46±18.66 cm H2O ($p < 0.001$) and an increase in maximal expiratory pressure (MEP) from 71.69±20.01 cm H2O to 78.92±21.45 cm H2O ($p < 0.001$) [7]. The results of the study are positive-an improvement in lung function was obtained in the intervention group. Taiwanese researchers conducted a study in which children were divided into two groups of 15. The study group trained in swimming for six weeks in addition to regular drug treatment. Pulmonary function tests, PEF and asthma severity scores were measured to assess the results. After swimming training, a significant improvement ($P < 0.01$) in peak respiratory flow (PEF) was observed in the experimental group compared to the control group (330 L/min, 95% CI: 309-351 vs. 252 L/min, 95% CI: 235-269) and a statistically significant improvement ($P < 0.05$) in asthma severity was observed in the experimental group compared to the control group. No improvement was observed in spirometry testing. The results are therefore promising and suggest a positive effect of swimming on some respiratory parameters and symptoms [8]. A meta-analysis conducted by UK researchers showed that asthmatic children achieved a significant improvement in PEF after swimming training compared to the control group (MD 63.49 L/min, 95% CI 25.01-101.97, $I^2 = 52\%$, 38 participants), the improvement in the PEF parameter was greater in

children with asthma than in healthy children. In addition, swimming reduced symptoms of bronchospasm after exercise and reduced bronchial hyperresponsiveness [9].

Effect of swimming pool attendance on the development of asthma and airway dysfunction

A meta-analysis published in 2021 examined the effect of swimming training in children up to 18 years of age on lung function - noted significant improvements, especially in FEV1 and FVC% with no clear effect on PEF% and percentage FEV1 [6]. In 2014, a study of a population of Dutch children attending a swimming pool between the ages of 6 and 13 years was published to assess the effect of pool use on respiratory well-being. No association was found between pool use (either indoor or outdoor) and respiratory symptoms. Interestingly, it was found that swimming in indoor pools was associated with higher rates of sensitisation, to birch (OR=5.63) and house dust mites (OR=1.86), and children who swam at least once a week before the age of 2 years were more likely to be sensitised to these allergens [10]. Another study of children attending kindergarten found that going to a chlorinated swimming pool before the age of 2 years increased the risk of bronchiolitis (OR 1.68; 95% CI 1.08-2.68; p=0.03), and this risk depended on the level of exposure for both types of pool- indor and outdoor pools (($p < 0.01$), which was also associated with a higher risk of developing asthma and allergies in the future [11]. In contrast, another study found that going to a swimming pool before 2 years of age was associated with a slightly lower incidence of asthma (OR 0.79, 95% CI 0.43-1.46), rhinitis (OR 0.86, 95% CI 0.68-1.08) and allergic rhinitis symptoms (OR 0.72, 95% CI 0.54-0.96) compared to children who started attending a swimming pool after 4 years of age, with 95% of participants attending chlorinated pools [12]. In the cited studies, children from more affluent families were more likely to attend the pool [11,12, 14]. A population-based study showed that the use of indoor swimming pools (≥1 time per week) was significantly associated with an increased risk of asthma among allergic children. This risk, was significantly higher compared to non-allergic children. [13]. In the UK cohort study 'Avon Longitudinal Study of Parents and Children', swimming was not shown to increase the risk of asthma, and swimming was associated with improved lung function and reduced asthma symptoms, in addition, children who swam more often had better lung function test scores [14]. In a large meta-analysis on the association between swimming and asthma, no statistically significant increase in the risk of asthma was found among children attending a swimming pool (Meta-OR was 0.82) [4]. As can be seen, the research on the effect of swimming pool on airways is inconclusive and there is a need for further research. In a large meta-analysis evaluating the effects of swimming on the human body, it was noted that in healthy children and adults, swimming significantly improved PEF compared to the control group. A meta-analysis of three randomised controlled trials (RCTs) found a significantly higher PEF in the swimming group (mean difference MD 58.74 L/min, 95% CI 29.70-87.78) [9].

Competitive swimmers

As everyone knows, many athletes in various sports suffer from asthma. Swimming is no exception and some professional swimmers suffer from bronchial asthma. Does their competitive training affect the course of their disease? We will try to answer this and many more questions in this chapter.

In a study of 200 Finnish male and female swimmers, it was found that 16% of the swimmers declared that they had doctor-diagnosed asthma (12% of whom had exercise-induced asthma). 42% declared that they experienced asthma symptoms such as shortness of breath, wheezing, coughing and mucus production during intensive swim training [15].

In a study of 1118 swimmers (competitive, fitness and recreational), as many as 18% reported experiencing respiratory symptoms during training. Competitive swimmers reported statistically significantly more respiratory symptoms compared to fitness swimmers (OR 2.31) and occasional swimmers (OR 5.27); additionally, swimmers who spent more than 90 minutes in the water also reported more symptoms (OR 2.66) and those who covered a distance greater than 2,000 metres (OR 2.91). Spirometry performed on professional swimmers showed that 12% had symptoms of bronchial obstruction. The researchers noted to their surprise that some of the asthmatic swimmers with obstruction on spirometry were not taking anti-asthmatic medication at all [16]. A study was conducted to document changes in airway reactivity and airway inflammation in elite swimmers during intensive training and rest. For this purpose, 19 swimmers were selected and examined during intensive training and after a minimum of 2 weeks of rest. Airway reactivity to methacholine and eucapnic voluntary hyperpnea was significantly higher in swimmers than in controls ($P < 0.0001$), a significant decrease in airway reactivity from training to rest was recorded only in swimmers ($P < 0.005$). It was found that up to 76% of swimmers presented airway hyperresponsiveness (AHR), but after a minimum of 2 weeks rest, swimmers' AHR partially normalised in 67% of cases among swimmers. Despite the presence of AHR, persistent cellular infiltration in sputum was not observed [17]. A study of 47 licensed swimmers showed that they were often accompanied by bronchoconstriction induced by exercise (bronchospasm caused by intense physical activity) without accompanying asthma and non-allergic rhinitis [18]. Studies assessing ventilation have shown that there is an increase in FVC and a decrease in FEV1/FVC after training [18, 19]. This phenomenon has been explained by researchers as an increase in lung volume without a proportional increase in airway count and suggests that swim training may induce an increase in lung capacity [19]. In a meta-analysis, elite level swimmers showed a higher risk of asthma compared to other athletes. The meta-OR ranged from 2.29 to 2.57, suggesting that asthma is more frequently diagnosed in this group [4]. Elite swimmers, due to the number of hours they spend in the pool, are exposed to chlorine for long periods of time. A study of 23 elite swimmers swimming in chlorinated pools showed that the swimmers had higher FEV1 and FVC values compared to a group of asthmatics and healthy controls, 52% of the swimmers had a PC20 FEV1 below 16 mg/mL, indicating airway hyperresponsiveness, in addition, they had higher eosinophil and mast cell counts and increased numbers of goblet cells and collagen I and III type and tenascin in the airways. In conclusion, intensive training in influenced the lung function of elite swimmers by increasing lung capacity, but may lead to airway hyperresponsiveness, inflammation and structural changes in the lungs [20].

Another issue the researchers tried to address was the difference between the incidence of gender differences in the context of asthma symptoms. In a study conducted on swimmers and tennis players. It found that women had a higher prevalence of exercise-related asthma symptoms and higher airway reactance compared to men [21].
A study was conducted on a group of 101 swimmers aged between 13 and 23 years, training between 10 and 30 hours per week, to investigate the effects of intense physical activity, especially in the context of swimming in chlorinated pools, on the occurrence of respiratory symptoms, among other things.

Asthma symptoms (including shortness of breath and wheezing) were significantly more frequent among the swimmers, with a frequency of 36.6% (compared to 16.2% in the control groups), and they also reported more episodes of nocturnal cough and wheezing. The swimmers surveyed did not smoke cigarettes and consumed alcohol significantly less often and their diet was healthier. In addition, they rated their quality of life higher, had fewer psychosomatic complaints, higher well-being and self-esteem [22].

Impact of the use of chlorine and other disinfectants in swimming pools
Chlorine compounds, other biocides and detergents are used in sports facilities such as swimming pools. In Poland, there are guidelines on water quality requirements and sanitary and hygienic conditions in swimming pools promulgated by the Chief Sanitary Inspectorate, which are based on recommendations of the World Health Organisation (WHO). It is the responsibility of swimming pool administrators to assess water quality on a regularly scheduled cycle. Among the components of the analysis is the assessment of the disinfectant concentration, which in most cases is chlorine [23]. Consequently, people attending swimming pools are exposed to the potential irritant and sensitising effects of chlorine and the generated chloramines. A reliable assessment of the impact of swimming pool training on asthma and other respiratory disorders requires looking at the potential impact of the chemicals used in swimming pools.
A case-control study was conducted in Sweden on a group of asthmatic and healthy children attending a swimming pool. The researchers measured the concentrations of trichloramine-generated by the chlorination of water in swimming pool buildings. This was to assess whether the children were exposed to high concentrations of it before the onset of asthma symptoms. Exposure to trichloramine in swimming pools, has been shown to be associated with an increased risk of developing asthma in children, particularly between the ages of 0 and 6 years, and children exposed to trichloramine before the age of 1 year had almost double the risk of developing asthma. No association was found between trichloramine exposure and the occurrence of asthma after the age of 7 years [24]. The risk of developing asthma was higher when both trichloramine exposure and positive allergic skin tests to inhalant allergens were present - sensitised children who were exposed to trichloramine had twice the risk of developing asthma compared to sensitised children who were not exposed to trichloramine [24].
In a study in mice assessing the effect of disinfection by-products (DBP) released during the disinfection process-on airway inflammation and the occurrence of asthma symptoms. The

results indicate that swimming, despite the presence of DBPs in pool water, has a beneficial effect on the immune system by increasing T-cell counts and that the benefits of regular pool exercise outweigh the possible risks [25]. A large meta-analysis involving a total of 5851 children to assess the impact of swimming pool disinfection by-products found no statistically significant increase in the risk of asthma diagnosis in children attending indoor swimming pools- the OR was 1.08, (95% CI: 0.898-1.307; P = 0.4) [26]. A study involving elite swimmers (a number suffered from asthma) was established to assess the effect of swim training on oxidative stress markers. Participants in the study had exhaled air samples collected before and after a training session in a chlorinated pool. Metabolites, which are the end products of lipid peroxidation, were analysed. Oxidative stress was analysed for its association with the occurrence of asthma.
After training, a decrease in metabolites was recorded in both the asthma group and the control group, with the non-asthma group having a greater decrease [27].

Occupational respiratory exposure to chlorine and other substances used in swimming pools

Occupational exposure to chlorine and its by-products affects workers in these facilities, such as lifeguards and maintenance workers. Due to the prolonged daily exposure, they are particularly exposed to the volatile compounds released. For this reason, we devote a chapter of this article to analysing the effects of these substances on the respiratory tract in occupationally exposed people.
In an American study that included workers in swimming pools, aquaparks and similar facilities who presented with occupational asthma symptoms as a result of exposure to chlorinated water. Working in a swimming pool environment was shown to be associated with occupational asthma, and 56.8 per cent of cases were newly diagnosed - exposure to chloramines and other disinfectant products used in swimming pools can induce asthma symptoms. Researchers suggest that chloramines are the main inducer [28]. An observational study based on a case study of pool workers who reported asthma symptoms that worsened at work and resolved after a day off showed that exposure to nitrogen trichloride (NCl_3), which is a by-product of the reaction of free chlorine used for disinfection with contaminants (e.g. sweat, urine) induced asthmatic reactions in a challenge test. Importantly, the chlorine challenge test was negative [29]. However, it should be noted that the above result concerns a very small group and may inspire further research rather than drawing firm conclusions.
In Sweden, a study was carried out on a group of 146 swimming pool workers in various positions. 17% of indoor pool workers reported work-related respiratory symptoms such as cough, hoarseness. Rates were highest among those with 1-3 years of experience (31%). No statistically significant association was found between trichloramine levels and the occurrence of respiratory symptoms. Nasal lavage fluid analyses found higher concentrations of alpha-1-antitrypsin and lactoferrin proteins and lower concentrations of S100A8 (another name is calgranulin A) among pool workers, especially in symptomatic individuals [30]. The cited study did not confirm the involvement of trichloroamines in the induction of respiratory tract irritation symptoms.

In Taipei, a study was conducted on employees of 10 indoor swimming pools. The study group consisted of employees such as lifeguards, swimming instructors (employees who had higher exposure to trichloramine) and the control group consisted of employees who did not work near chlorinated water (e.g. receptionists). It was shown that even at low concentrations of NCl_3, (0.017-0.15 mg/m³, the WHO recommended standard is a maximum of 0.5 mg/m³), workers experienced symptoms of respiratory irritation. The study group, compared to the control group, had a significantly higher risk of sore throat (OR = 11.28) and expectoration of sputum (OR = 4.22). The study shows that even much lower than maximum permissible values of trichloramine can cause somatic respiratory symptoms [31].

Conclusion

The effect of swimming training on bronchial asthma and its impact on lung function parameters is a topic that has interested researchers for many years.

Many large and valuable studies have been produced, especially on the population of children and adolescents on this topic. Based on the analysed literature, it can be concluded that swimming has a beneficial effect on the condition of asthmatic patients, improving spirometric parameters and thus lung function. In addition, swimming training results in a significant reduction of asthma symptoms such as wheezing. However, there are indications that exposure to chlorine and its by-products may pose a risk to respiratory well-being, especially among the pediatric population and those doing long training sessions in chlorinated pools. Swimming can improve the overall physical performance and quality of life of people with asthma, but unfortunately carries the risk of exposure to the irritant effects of chlorine and its by-products, which is of particular concern among professional swimmers and pool workers. Although the topic of swimming and asthma has been studied for a long time, more research is still needed to further define the impact of the training itself as well as the potential exposure to chemicals used in swimming facilities. There is relatively little research on the adult population, especially recreational swimmers. It is definitely an area worth investigating what effects swimming training will have on adults, especially those with a long history of bronchial asthma. Another field worth investigating is the comparison of training in chlorinated pools with training in pools treated with, for example, ozone.

Clearly, asthma is a serious public health problem and the results regarding the positive effects of swimming on asthma are strong and convincing. The results show that in most cases, the benefits of swimming outweigh the potential risks.

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Author's contribution:

Conceptualization: Anita Ptak, Michał Szyc

Methodology: Michał Szyc, Anita Ptak

Software: Michał Szyc

Check: Anita Ptak

Formal analysis: Michał Szyc, Anita Ptak
Investigation: Michał Szyc, Anita Ptak
Resources: Michał Szyc, Anita Ptak
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