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Effects of Physical Activity on the Course of Bronchial Asthma and the Relationship Between Asthma and Competitive Sports - a Review of the Literature

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ABSTRACT

Introduction:

The symptoms of bronchial asthma, triggered in response to physical and chemical factors, including allergic and non-allergic ones, contribute to a progressive decline in physical condition, both through a decrease in the frequency of physical exercise practiced by patients and in the lack of symptom control caused by inadequate treatment or coexisting aggravating factors. Due to the frequent development of bronchial hyperreactivity and the prevalence of asthma in athletes, particularly competitive athletes, it was thought until recently that physical activity, whether work-related or sports-related, was inadvisable in asthma.

Aim of the study:

The purpose of this paper is to summarize the state of knowledge regarding the effects of competitive sports on the development of asthma, and to provide evidence that moderate physical activity can in turn complement its treatment.

Materials and Methods:

We conducted a comprehensive search of the PubMed electronic database and Google Scholar to identify relevant studies published between 1989 and 2023. Inclusion criteria encompassed studies focusing on human populations, also including studies conducted in animals. Articles in languages other than English, case reports and editorials were excluded.

Conclusion:

A review of the literature indicates that prolonged and intense exposure of athletes to cold air, inhaled harmful chemicals, hyperventilation and intense exercise can result in increased inflammation in the airways, increased sputum production, smooth muscle contraction and bronchial obstruction. However, a growing number of recent studies indicate that regular and moderate physical activity, such as aerobic training, can help improve the overall cardiopulmonary capacity of patients with asthma, reduce coexisting risk factors such as obesity, and improve symptoms control, reduce inflammation, slow the decline in spirometric parameters and disease progression, particularly in children.

Keywords: asthma, bronchial hyperreactivity, competitive sports, inflammation, symptoms control, aerobic training

1. Introduction

Bronchial asthma is a chronic inflammatory disease of the respiratory tract of allergic or non-allergic origin, associated with attacks of dyspnea due to bronchial obstruction and excessive mucus production, in response to allergic factors, chemical factors such as in the workplace, physical factors such as cold air, or tobacco smoke and air pollution, among others [1]. For years there has been an upward trend in the incidence of the disease, both in children and adults [2], with more than 339 million people worldwide currently affected [3]. The disease, due to its characteristic symptoms and course, is associated with the risk of progressive decline in overall physical condition, which is influenced by several factors:

- a decrease in the frequency of patients' exercise and sports, due to, among other things, fear of a dyspnea attack, inadequate education or lack of symptom control [4],

- airway inflammation, associated with obstruction and excessive sputum production, which translates into a decrease in FEV1 and FVC and an increase in PEF variability, resulting in a decrease in respiratory capacity [5],

- treatment that does not provide adequate disease control, or lack of treatment and co-morbidities or prognostically unfavorable factors, i.e., obesity [6], low economic status [7], exposure to tobacco smoke, especially in childhood [8].

Until recently, it was thought that physical activity, whether work-related or sports-related, was inadvisable in the course of bronchial asthma, due to an increased risk of triggering an attack, and poorer symptom control [9]. In competitive athletes engaged in heavy endurance sports for many years, it has been observed that prolonged exposure to cold air, dust and pollutants, hyperventilation, high airway flow rates, and the stress of intense exercise cause bronchial hyperreactivity and frequent bronchial asthma, particularly in swimmers and skiers [10, 11]. A high need for inhaled medications has also been observed [12]. In addition, studies analyzing the levels of inflammatory exponents and the infiltration of eosinophils and neutrophils indicate increased inflammation in professional athletes [13, 14].

However, a growing number of studies indicate that regular and moderate physical activity, such as aerobic training, can improve asthma control [15], reduce inflammation [16], slow the decline in spirometric flow parameters, i.e. FEV1 and FVC [17], and improve overall organismal capacity and slow disease progression, particularly in the pediatric population [18]. In this paper, we present a review of studies indicating that such activity should not be abandoned, but rather treated as an adjunct to pharmacological and non-pharmacological treatment of asthma [19].

2. Asthma and bronchial hyperreactivity in athletes

2.1. Review of reports

In 1989, an increase in nonspecific bronchial reactivity after heavy endurance training was observed in young competitive swimmers aged 12-18 years who swam 3000 meters [20]. The increase in bronchial reactivity correlated with an increase in training load (an increase in blood lactate concentration) in both asthmatic and healthy swimmers. In contrast, Larsson and colleagues [10] in 1993 showed a high prevalence of bronchial hyperreactivity and asthma among cross-country skiers in Sweden, and two years later Heir and Larsen [21] reported on the effect of training intensity, respiratory infections and environmental conditions on the incidence of bronchial hyperreactivity among endurance-trained, young Norwegian cross-country skiers. Wilber et al. [22] later reported similar results in U.S. athletes at the Winter

Olympics, which was confirmed by a further study by Rundell et al. [23]. Sue-Chu et al. [24] in 1998 showed that young cross-country skiers showed signs of inflammation (lymphoid follicles and tenascin deposition) in bronchial biopsy specimens during a single winter season, regardless of whether they had asthma or not. In 2012, these bronchial biopsy results in cross-country skiers were confirmed by similar results in swimmers [25]. K. Fitch reported that during the last three Summer Olympics and the last three Winter Olympics relative to 2008 [12], the use of asthma medications, particularly inhaled b2-mimetics, was highest in cross-country skiing and speed skating, followed by cycling, nordic combined (both cross-country skiing and ski jumping) and swimming.

In 2009, Bougault et al. [13] reported the results of a study of induced sputum and eosinophil and neutrophil cell counts in swimmers and athletes involved in cold-air sports (cross-country skiers, speed skaters and biathletes) compared to a control group of healthy subjects and a control group of patients with bronchial asthma. Bougault et al. reported that 69% of swimmers and 28% of cold-air athletes showed bronchial hyperreactivity after methacholine administration. Induced sputum showed increased numbers of bronchial epithelial cells and neutrophils, with the number of neutrophils independent of bronchial hyperreactivity and correlated with the number of training hours per week. The number of eosinophils increased only in swimmers and cold-air athletes with bronchial hyperreactivity present and correlated only in swimmers. These findings are consistent with those of Helenius et al. [14], who also reported increased levels of eosinophils and neutrophils, as well as increased levels of eosinophil peroxidase and human neutrophil lipocalin in induced sputum in swimmers. Similar relationships have been observed in animal studies. In 2002, Davis et al. [26] performed bronchoscopies and bronchoalveolar lavage studies in racing dogs, 24-48 hours after completing an 1100-mile endurance race in Alaska. Of the 59 dogs examined, 48 showed abnormal accumulation of debris in the bronchial lumen, and BALs taken after the race showed significantly higher numbers of multinucleated macrophages and eosinophils compared to a control group of dogs with a sedentary lifestyle.

2.2. Analysis of potential causes

The reasons for the above phenomena are attributed both to the effects on the respiratory tract of cold air and hyperventilation, as well as to specific environmental exposure to harmful chemical compounds characteristic of a particular sport.

First of all, physical activity causes an increase in minute ventilation and thus increased water and heat loss through respiration. Cold air reflexively activates parasympathetic impulses causing bronchoconstriction and, initially, reflex constriction of bronchial venous vessels to conserve heat. Once exercise is stopped, the increased ventilation ceases, and with it the cooling stimulus, causing rebound vasodilation. This causes both smooth muscle contraction, due to nerve stimulation, and mucosal edema, due to vasodilation in vulnerable individuals [27], reducing the size of the bronchial lumen with increased airway resistance [28]. Secondly, increased water loss due to increased minute ventilation increases the osmolality of the extracellular fluid of the bronchial mucosa and osmotic outflow of intracellular water into the extracellular space [29], resulting in an increase in the concentration of ions inside the epithelial cells of the bronchial mucosa [30]. This process results in an increase in inflammatory mediators, i.e. eicosanoids synthesized de novo, or histamine released from intracellular granules, which exacerbate swelling and bronchial obstruction. Endurance runners, on the other hand, showed increased bronchial epithelial cell counts and bronchial cell apoptosis in induced sputum developing during repeated half marathons along with increased levels of serum CC16 and interleukin (IL)-8 supernatant in induced sputum [31]. The association with airway epithelial damage during intense exercise is also indicated by the overproduction of mucin and the presence of increased levels of cysteinyl leukotrienes and histamine in induced sputum, as well as increased expression of MUC5AC in patients with exercise-induced bronchial hyperreactivity [32].

Professional swimmers are particularly exposed to organochlorine products used to disinfect water in indoor pools [33]. Bernard et al. in 2003 and 2006 [34, 35] showed that there is an association between the number of hours spent in indoor swimming pools and the risk of developing asthma in preschool and school-aged children. Serum concentrations of surfactant proteins A and B [34] and Clara exocrine cell bronchial proteins [36] have been linked to lung damage caused by attending a swimming pool in childhood. Bernard et al. in 2008 [37] also reported an increased risk of asthma associated with attending chlorinated outdoor pools. Athletes training and competing on ice rinks may be exposed to NOx from freezing machines, as well as ultrafine particles from resurfacing machines [38], consistent with reports of high prevalence of asthma among hockey players [39] and figure skaters [40]. A study in Southern California (USA) involving 3,535 children living in six high-pollution (ozone) areas and six low-pollution areas found after a 5-year follow-up that children actively participating in more than three sports in high ozone areas had an increased risk of asthma. Participation in sports in low ozone areas was not associated with an increased risk of asthma [41].

2.3.Conclusions and implications

Different types of sports will have different environmental exposures, and pollutants and harmful chemicals in the air increase the risk of asthma and bronchial hyperreactivity in athletes. In addition, the mechanism for the development of hyperreactivity is compounded by the effect that hyperventilation and cold air under conditions of intense exercise have on the airways. The above physical and chemical factors contribute to the development of inflammation, excessive sputum production and bronchial obstruction in vulnerable individuals. This carries with it the following clinical implications: appropriate consideration of risk factors in athletes with newly diagnosed asthma symptoms, which should be taken into account in treatment, as well as careful selection of competitive sports activity in individuals with a history of allergy and personal and family history of lung disease.

3. Effect of moderate physical activity on the risk of asthma development

A 2012 meta-analysis by M. Eijkemans et al. [4] compared the results of 39 studies, including five cohort studies and 34 cross-sectional studies. The cohort studies looked at subjects' physical activity levels at the beginning of the study and asthma occurring during follow-up. The duration of follow-up ranged from 5 to 10 years. Physical activity was assessed by questionnaires - a total of 85,117 participants - and it was shown that people with higher levels of physical activity may have a lower risk of developing asthma. Of the cross-sectional studies, the vast majority (25 studies) included children of different ages, eight studies included adults only, and one study included both children (aged 12 and older) and adults. In some of the studies involving children, physical activity was assessed using motion sensors, while the remaining studies used questionnaires. A total of 13 studies (564,394 people) found a statistically significant association between high levels of physical activity and lower asthma prevalence, 3 studies (1,773 people) found a statistically significant association between high levels of physical activity and higher asthma prevalence, and 18 studies (95,055 people) found no significant results. A significant number of included cross-sectional studies, with the largest total study population, showed an association between high levels of physical activity and lower asthma prevalence.

4. Effect of moderate physical activity on the course of already diagnosed asthma

It should be noted that most studies analyzing the effects of physical activity on asthma differentiate between sports and recreational activities and physical work. According to the WHO definition, physical activity is any bodily movement that results from the expenditure of energy by the skeletal muscle system. Exercise is a planned, structured, repetitive and purposeful physical activity that aims to improve or maintain one or even several elements of physical fitness [42].

4.1.Review and results of studies from recent years

A randomized controlled clinical trial by Jouni J. K. Jaakkola et al. in 2019 [43] involving the introduction of a 24-week period of regular exercise in a group of adults with mild to moderate asthma and examining its effect on disease control showed that a regular exercise program improves asthma control in adults, as assessed by the Standardized Asthma Control Test (ACT). This test is based on subjective assessment of five elements related to asthma control - dyspnea, personal assessment of asthma control, use of rescue medication for asthma, work/school restrictions due to asthma, and waking up with asthma symptoms. The ACT ranges from 5 to 25 points, with 25 points representing the best and 5 points representing the worst control. The intervention group consisted of 16- to 65-year-olds with diagnosed mild to moderate bronchial asthma, who were previously trained by a nurse and instructed to perform aerobic exercise at least three times a week for at least 30 minutes. They were given individualized advice on various forms of aerobic exercise. Suggestions included brisk walking, jogging, running, Nordic walking, skiing, cycling, team games, dancing and gym exercises, such as with weights, a rowing ergometer or cross-training. The target heart rate was 70-80% of maximum heart rate, which was measured with a spiroergometer at the beginning of the study. Participants were advised to perform interval training if exercise caused asthma symptoms. They were also advised to moderate their training on cold days (temperatures below 10 °C). They were advised to avoid strenuous exercise during high concentrations of pollen to which they were allergic. In addition, they were advised to perform muscle exercises to strengthen their abdominal, back, upper body and thigh muscles at least twice a week. Participants were instructed to stretch before and after aerobic and muscle exercises. All participants were asked to note in their diaries the duration, intensity and form of the exercises they performed daily. In addition, they were asked to note in their diaries any potential asthma symptoms and activity limitations. They were also asked to take PEF measurements using the Vitalograph asthma-1 electronic respiratory monitor twice a day for one week every four weeks. Baseline measurements, including spirometry and a muscle strength test, were taken before and after the 24-week exercise period. In addition, the 6-minute walk test was performed three times during the study: at baseline, after 3, and after 6 months of follow-up. Quality of life was assessed using the St. George's Respiratory Questionnaire (SGRQ) at the beginning, middle, and end of the follow-up period. The research nurse randomized 164 eligible participants individually and independently by drawing the exercise intervention group or the control group. This was an open-label study, as participants could not be blinded due to the nature of the intervention.

The exercise interval, on the other hand, had little effect on reducing PEF variability. Planned a priori subgroup analyses showed that the observed beneficial effects of disease control were present mainly in young women and never smokers. Post hoc subgroup analyses also indicated beneficial effects in normal-weight subjects and those who exercised less at the start of the study. ACT improved in a significantly higher percentage of participants in the study group (62%) compared to the control group (39%). The use of short-term medication was also statistically significantly reduced in the intervention group compared to the control group. The overall effects of exercise as to the sensation of dyspnea were clearly positive, showing a 30% improvement. There were no significant differences as to change in the intensity of wheezing, coughing or secretion formation between the groups, nor in the variability of PEF.

The results of the above study were compared with those of 3 other RCTs published shortly before or during the study:

- França-Pinto et al. [44] conducted an RCT involving 58 patients with asthma in São Paulo, Brazil. Patients were randomly assigned to a 12-week aerobic training group and a control group. Aerobic training was found to reduce asthma exacerbations and improve quality of life as measured by the AQLQ - Asthma Quality of Life Questionnaire, but there was only a small, non-statistically significant effect on asthma control as measured by the ACQ - Asthma Control Questionnaire (0.2 points, 95% CI -0.3 to 0.7, P = 0.457).
- Freitas et al. [45] conducted an RCT involving 55 patients with asthma who were participating in a weight-loss program in São Paulo, Brazil. The obese asthma patients were randomly assigned to a 12-week aerobic and strength training group, subjected to nutrition (calorie restriction) and psychological therapies, and a control group with a general weight loss program. The exercise intervention improved the ACQ score in 69% of subjects, while 36% of subjects improved their score in the weight loss program-only group. The ACQ score improved by an average of 0.9 points (P < 0.001) in the exercise intervention group, while no such effect was observed in the weight loss-only group through diet.
- Toennesen et al [46] conducted an RCT of 125 patients with asthma in Copenhagen, Denmark. Adults without obesity were randomly assigned to exercise intervention groups, a diet group, a group in which exercise and diet were combined, and a control group during the 8-week study. The exercise intervention improved ACQ scores by an average of 0.4 points (95% CI: -0.01 to 0.78, P = 0.06).

This study was smaller and had a shorter intervention period compared to the previous study. They included intensive, supervised aerobic exercise, while the intervention in the Jouni J. K. Jaakkola et al. study included a personalized exercise program consisting of aerobic exercise, as well as muscle training and stretching. This type of intervention can be easily applied in clinical practice. The main outcome was based on a comparison of the number of people who improved asthma control, and the effect estimate was statistically significant, showing a 30% improvement.

Heikkinen et al. [47] studied the relationship between the amount of regular exercise and asthma control among 162 young adults with asthma recruited from the Espoo Cohort Study. Asthma control was assessed by the prevalence of symptoms, including wheezing, shortness of breath, coughing and phlegm production in the past 12 months. These were less common among those who reported regular moderate exercise. The association was strongest among those who were overweight.

Russell et al. [48] conducted a longitudinal analysis of the Bergen cohort, assessing the association of baseline physical activity with subsequent asthma, incident asthma and symptoms. Light but not intense physical activity was associated with lower subsequent asthma incidence.

Loponen et al. [17] studied the relationship between daily physical activity and lung function decline in 201 adult patients with asthma over a 12-year period after diagnosis. They found that the high physical activity group had a slower annual decline in FEV1 and FVC compared to the low physical activity group.

A systematic review and meta-analysis by Hansen et al. in 2020 [15] including 11 randomized controlled trials examining the effects of 8 weeks of aerobic training on asthma control, lung function and airway inflammation outcomes in adults with bronchial asthma, found that aerobic training had beneficial effects on asthma control and lung function, but not on markers of local airway inflammation. The exercise interventions mainly included walking, jogging, cycling, rowing, stair climbing and swimming. During the systematic evaluation of the quality of evidence, it was found that the included studies had several methodological limitations. In addition, heterogeneity, imprecision and inconsistency between studies were significant, and the overall risk of bias in each study was high due to the inability to blind the exercise intervention. The above meta-analysis treated the physical training interventions in the included studies as a single group. It should be noted that differences in the type, duration and intensity of physical training regimens undertaken most likely explain some of the heterogeneity between studies.

A systematic review of 23 randomized controlled trials conducted by Margaret M. Kuder et al. in 2021 [49] suggests that physical activity can improve asthma control, lung function and health care-related quality of life. None of the included studies showed worsening asthma control during physical activity interventions. Asthma control was assessed using questionnaires, i.e. the ACQ, while quality of life was measured using the AQLQ in most studies. In the above analysis, almost half of the studies showed evidence of improvement in lung function at rest after the exercise intervention, in terms of spirometric measurements. The six studies included in the above review also assessed changes in serum concentrations of certain inflammatory markers. Interleukin-6 (IL-6) was the most commonly measured biomarker, and 3 studies observed a decrease with the exercise intervention. None of the included studies assessed the effect of maintaining physical activity on outcomes for longer than one year.

A 2023 analysis of NHANES 2011-2020 (The National Health and Nutrition Examination Survey) data by Wei Ye et al. [7] showed that active work-related exercise increased the risk of triggering an acute asthma attack requiring emergency room intervention, while recreational exercise was not significantly associated with acute attacks of the disease. A closer analysis of additional factors suggested that the association between physical training and emergency room visits was influenced by gender, race, education, economic level and smoking history. In a study analyzing data from the 2010-2015 National Hospital Ambulatory Medical Care Survey (NHAMCS), asthma-related ER visits and post-operative hospitalizations were more common in children, black and Hispanic patients [50]. However, this study has some limitations, namely, its results only assessed the association between physical activity of physical labor and recreational forms and asthma attacks/acute care admissions, while specific types of exercise were not considered.

5. Effects of different exercise activities on spirometric parameters

In a 2023 meta-analysis by Shuangtao Xing et al. [51] that included 28 randomized controlled trials involving 2,155 patients with asthma, the effect of various exercise activities on specific parameters in a spirometric test was demonstrated. Compared to the control group:

- Respiratory training, aerobic training, relaxation training, yoga training and respiratory training combined with aerobic training improved the level of forced expiratory volume in 1 second (FEV1) and reduced the variability of peak expiratory flow (PEF).
- Aerobic training, respiratory training, yoga, and respiratory training combined with aerobic training improved the level of forced vital capacity (FVC).

- Respiratory training, aerobic training and yoga improved the ratio of first-second expiratory volume to forced vital capacity (FEV1/FVC).

SUCRA probability ranking results showed that:

- Relaxation training had the most significant effect on improving FEV1 levels.
- Respiratory training combined with aerobic training had the most significant effect on improving FVC levels.
- Yoga training had the most significant effect on reducing PEF variability.

6. Discussion

Previous studies have already shown that training improves cardiorespiratory capacity, asthma symptoms and patients' quality of life [52]. This evidence suggests that training and high levels of physical activity may play a role in the course and control of this disease. In addition, an etiological link between physical activity levels and the development of incident asthma is also possible.

Various hypotheses have been put forward to explain the potential protective nature of physical activity on the development of asthma, such as reducing airway inflammation, a major feature of asthma [53]. Animal models suggest that physical training reduces airway reactivity [54] and inflammation in mice [55]. In a Brazilian RCT, a 12-week aerobic training program reduced both BHR and the pro-inflammatory serum cytokines, interleukin-6 (IL-6) and monocyte chemoattractant-1 (MCP-1), and reduced sputum eosonophil counts and exhaled nitric oxide (FeNO) fraction in asthmatic patients with greater inflammation. There is evidence for the importance of IL-6 and MCP-1 in airway inflammation and BHR in asthma [56]. The reduction in FeNO suggests that aerobic exercise reduces airway inflammation. IL-6 has also been shown to be elevated in obese patients with asthma [57], as well as in severe asthma [16]. Comparing physical activity with sedentary lifestyle in asthmatic patients, one study found no difference in airway inflammation, but showed a significant decrease in serologic C-reactive protein levels with increased physical activity [58].

Another explanation is that physical activity can positively affect bronchial patency, and exercise has a short-term beneficial effect on airway smooth muscle. Poor mucociliary clearance due to reduced epithelial stimulation secondary to reduced physical activity can cause excessive mucus secretion and airway edema. Reduced deep ventilation and sigh rate during physical inactivity can lead to smooth muscle contraction and a subsequent increased risk of asthma symptoms [59]. This is consistent with the idea presented in the American College of Sports Medicine guidelines, which suggest that although exercise may be a trigger for airway obstruction in asthmatics, it is possible to build up a tolerance to physical activity over time [60].

Various types of mechanisms have been proposed to explain the beneficial effects of regular aerobic training on asthma. Firstly, aerobic training improves cardiopulmonary capacity, as manifested by increased maximal oxygen consumption. Increased oxygen uptake capacity, along with an increased threshold for the onset of dyspnea, would help people with asthma cope with daily life at a lower level of exertion. It would therefore improve the effort-to-benefit ratio, leaving more respiratory reserves [61]. Aerobic training with special emphasis on diaphragmatic breathing facilitates the rhythmic contraction and relaxation of the diaphragm, leading to an increase in chest and abdominal pressure variability, providing better blood supply to the respiratory organs. Relaxation training can improve ventilation in asthmatic patients by reducing inhibitory impulses in the cerebral cortex, stabilizing the regulatory function of the neuroendocrine system, reducing the release of inflammatory mediators and relieving bronchial mucosal edema. In addition, yoga, which involves various twisting and bending movements of the torso, stimulates blood circulation, metabolic rate and expands the chest. Through this type of respiratory training, improvements in muscle activity and coordination of the respiratory cycle can be achieved, resulting in significant changes in intrapulmonary pressure, increased alveolar dilation and contraction, and airway expansion, reducing airway resistance and promoting lung ventilation and gas exchange. Therefore, yoga and respiratory training combined with aerobic training may be the most effective interventions to improve lung function in adults with asthma [62].

Currently, neither the Global Initiative in Asthma nor the National Heart, Lung, Blood Institute (NHLBI) Asthma Guidelines make specific recommendations for physical training or exercise as part of non-pharmacological treatment for asthma control [63]. Even the December 2020 update of the NHLBI Asthma Treatment Guidelines makes no mention of the potential benefits of physical activity [64].

7. Conclusion

A growing body of evidence suggests likely mechanisms that explain the beneficial effects of regular exercise on asthma control. In daily clinical practice, doctors should evaluate the possible benefits that regular and moderate physical activity can bring to patients and consider it as an adjunct to pharmacological and non-pharmacological treatment of asthma. Future research should focus on determining the effectiveness of different types, intensities and frequencies of exercise, as well as the potentially beneficial effects of combined endurance and aerobic training. Tailoring interventions to individual physical and mental health conditions, with careful consideration of exercise intensity, frequency and duration, is important to optimize treatment outcomes. Quality of life is a key factor when considering therapeutic interventions, as it aims to assess a patient's perception of well-being, as part of a more holistic approach to overall patient assessment [65].

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