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Physiological Benefits of Physical Activity in Asthmatic Population

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Abstract

Asthma is a chronic respiratory disease characterized by difficulty in breathing due to respiratory inflammation and hyperreactivityof the airway smooth muscle. The typical clinical asthma symptoms, breathlessnessand wheezingmay occur several times a day or week in affected individuals, and for some people become worse during physical activity or at night. The pharmacological treatment includes the use of bronchodilators to relieve smooth muscle contraction, drugs to stabilize mast cells that release histamine, and anti-inflammatory drugs, including corticosteroids. People who suffer from asthma can participate in all types of exercise and physical activity, in the same way, people without asthma. A program consists at least 20-30 minutes per day; 2-3 days per week, 60% $\dot{V}O_2$peak or 80% of maximal walking speed from 6-minute walk test is suggested. Strength training included 70% of 1 RM, 2 or more sessions per week, 2-3 sets of 8-12 repetitions are desirable. People with exercise-induced bronchoconstriction should inhale beta-2 agonists 15 min to 30 minutes before exercise,and seekadvice from a medical doctor before undertaking regular exercise training protocol.

Keywords: exercise-induced bronchoconstriction, training effect,exercise recommendation

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I. INTRODUCTION

Asthma is a chronic and non-communicable disease caused by airway inflammation and hyperreactivity of the smooth muscle of the respiratory tract. This inflammation results in mast cell infiltration, inflammatory cells and mucus, results in difficulty in breathing. Furthermore, the swelling of smooth muscle in the bronchus leads to airway narrowing. This condition results in chest tightness, wheezing, pain, cough, and shortness of breath (World Health Organization [WHO], 2015).

Asthma has been found to be the 14th most common disorder in the world in terms of the extent and duration of disability (Asher & Pearce, 2014; Global Asthma Network, 2014). The incidences of asthma reported by Global Asthma Network (2014) indicated that 334 million people have suffered from asthma. It estimated 14% of the world children experience asthma symptoms, 8.6% of young adults (aged 18-45) experience asthma symptoms, 4.5% of young adults have been diagnosed with asthma and/or taking treatment of asthma. The greatest burden of asthma is for children aged 10-14 years old and the elderly aged 75-79 years old. The number of people in each group with asthma increases every year.So, more attentionis neededdnot only from governments, but also from the public as well.

Asthma is the most common paediatric chronic disease. In children, exercise-induced bronchoconstriction (EIB) may be the first presentation of asthma (Philpott, Houghton & Luke, 2010). Fifty per cent of asthmatic students have reported that they are less engaged in physical activity (PA). They and their parents worry about having an asthma attack during PA (De Bisschop, Guenard, Desnot, &Vergeret, 1999). Also, Chiang, Huang & Fu (2006) found that the frequency and number of exercise periods per week are lower for asthmatic students. This shows that solutions are needed to encourage asthmatic students to participate more in PA. However, due to the limited information available, in the areas of sports science and physical education teaching, it is imperative that we have a better understandingof the importance of this disease so thatchildren'senjoyable PA and safetycan be guaranteed.

This paper covers pathology of asthma, incidence and factors to induce asthma, treatment and prevention, physical training effect as well as exercise recommendation.

II. PATHOLOGY OF ASTHMA

2.1 Signs and Symptoms

The sign when people get asthma is knownas an asthma attack, the lining of the bronchial tubes swell, causing the airway to narrow, thereby reducing the airflow into and out of the lungs. The symptoms cause shortness

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of breath; coughing, wheezing and chest pain that impact upon the quality of life.(Akinbami, Moorman & Liu, 2011; WHO, 2015).

Many factors can lead to asthma. There are allergens, cold air, exercise, infections, pollutants, local neighbourhood (crime levels, food quality, and green space) and some drugs. Individual characteristics (age, sex, race, and genetics) and internal factors (obesity & stress) are also part of the trigger for asthma. The allergens divided into indoor and outdoor pollutants. Cigarette smoke (both passive and active smoker), chloramine in indoor swimming pools are indoor pollutants. Air pollutants such as particulate matter from combustion engines, dust, ozone, nitrogen oxides, sulphurs dioxide and carbon monoxide are some outdoor pollutants. Beta-blockers and non-steroidal anti-inflammatory drugs (NSAID) can provoke bronchoconstriction. The response to the triggers is different even though same asthmatic at different times (Bacharier et al., 2008; Beasley, 1998; Bloom, Jones, & Freeman, 2013; Morton and Fitch, 2011; Gupta, Zhang, Sharp, Shannon, & Weiss, 2008). These allergens make the symptoms of asthma getting bad.

During an asthma attack, the inflammation played a central role in the pathophysiology. Airway inflammation involves the interaction of many cell types and multiple mediators within the airways that eventually result in the characteristic pathophysiological features of the disease: bronchial inflammation and airflow limitation with recurrent episodes of a cough, wheeze, and shortness of breath. Moreover, although distinct phenotypes of asthma exist (e.g. intermittent, persistent, exercise-associated, aspirin-sensitive, or severe asthma), airway inflammation remains a consistent pattern. The pattern of airway inflammation in asthma, however, does not necessarily vary depending upon disease severity, persistence or the duration of disease. The cellular profile and the response of structural cells in asthma are quite consistent (National Heart, Lung, and Blood Institute,2007).

One of the causes of asthma is airway inflammation in the smooth muscle. Doeing and Solway (2013) concluded that airway smooth muscle (ASM) plays a role hyper-responsive contractile in the acute to chronic airflow limitation and a marker disturbance to relax also to pay attention in a therapeutic target. This finding was supported by Kudo, Ishigatsubo, and Aoki (2013), that ASM contraction, airway remodelling, and reversible airway obstruction is inducedby airway inflammation. When the airway getsinflamed the airway remodelling is increasing also myofibroblasts in the understructure of epithelium, the proximity of smooth muscle layer and the lamina reticularis. Epithelial to mesenchyme transition on asthma plays an important role in airway remodelling. These epithelial and mesenchyme cells cause persistence of the inflammatory

infiltrate and induce histological changes in the airway wall, increasing thickness of the basement membrane, collagen deposition and ASM hypertrophy and hyperplasia. Airway remodelling has been proven to make it harder for people to breathe.

Airway remodelling is a general term describing chronic, possibly irreversible changes that occur in the airways of patients with asthma. These include smooth muscle hypertrophy, angiogenesis and increased vascularity, chronic inflammatory cell infiltration, goblet cell hyperplasia, collagen deposition, thickening of the basement membrane and reduced elasticity of the airway wall (Bacharier et al., 2008; Bousquet et al., 2000).

Another symptom is immunity of the asthmatic patient whichis also part of the body defenses when getting an attack. Powers and Howley (2012) stated the immune response of asthma is that an antigen (or allergen) stimulates the B-cells to produce antibodies (immunoglobulin's [Ig]) to protect against a subsequent exposure to that allergen. However, in those who are genetically predisposed to have allergies, the B-cells produce IgE antibodies rather than IgG antibodies, which attach to the surface of mast cells lining the bronchial tubes. Upon re-exposure, the allergen binds to these IgE antibodies and the mast cell, and large amounts of various inflammatory mediators are released from the mast cell. These mediators include histamine, prostaglandin, and leukotrienes, and cause the early phase reactions: increased secretion of mucus, increased blood flow, swelling of the epithelial lining, contraction of smooth muscle surrounding the airway. These early-phase reactions may lead to late-phase reactions such asthe release of additional mediators from eosinophil's that prolong the inflammation process. These condition cause degenerate ability to breathe and induce an asthma attack.

The type of asthma can be classified according to symptoms such as recurrence rate and results of peak expiratory flow (PEF) or forced expiratory volume in one second (FEV1).Even if some signs and symptoms of asthma do exist, approximately 15% of asthmatics feel no discomfort even after an acute 20% reduction in their FEV1(Table 1) (Carlin &Seigneur, 2003).

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Table 1. Classification of asthma; clinical features before treatment (Carlin &Seigneur, 2003)

Category	Days with symptoms	Night with symptoms	PEF or FEV_1
severe persistent	Continual	Frequent	< 60%
moderate persistent	Daily	>5/month	> 60 - < 80%
mild persistent	3-6/week	3-4/month	> 80%
mild intermittent	< 2/week	< 2/month	> 80%

PEF = peak expiratory flow; FEV_1 = forced expiratory volume in 1 second

2.2 Incidence and Factors to Induce Asthma

For investigating the incidence of asthma, the World Health Survey (WHS) of 2002-2004 was performed in 70 countries on 178,215 persons aged between 18 and 45. Respondents answered questions about asthma symptoms as well as clinical diagnosis.The survey indicated thatglobal prevalence rates of doctor diagnosed asthma, clinical/treated asthma, and wheezing in adults was 4.3%, 4.5% and 8.6% respectively, with great variation from one surveyed country to another. For some pairs of countries, the reported incidence differed by more than twentyfold (To, et al, 2012).

The WHO has also reported that 235 million people suffer from asthma. It occurs in all countries regardless of the level of development. Over 80% of asthma deaths occur in low and lower-middle-income countries (WHO, 2015).

Besides, more than 32 million people in the United States have been diagnosed with asthma at some time. Of the 22 million US residents who currently have asthma, 12 million have had an asthma episode or attack over the past year. Four thousand people in the US die each year from asthma-related causes, and asthma is a contributing factor in another 7000 deaths every year (Centre for Disease Control and Prevention [CDC], 2009).

Within-population subgroups, the incidence was higher among females, children, persons of non-Hispanic black and Puerto Rican ethnicity, and persons with a low family income. Asthma emergency visit and hospitalization rates were higher among females than males, among children than adults, and among black than white persons (Akinbami et al., 2011). The prevalence of asthma increased from 7.3% in 2001 to 8.4% in 2010 (Akinbami et al., 2012).

Australia reported the highest rates of doctor diagnosed, clinical/treated asthma, and wheezing (21%, 21.5%, and 27.4%). Among those with clinical/treated asthma, almost 24% were smokers, and 20% had not previously been treated for asthma (To et al., 2012).

As for Taiwanese incidence data, an

international survey research, which included a population of 11,400 in Taipei, randomly chosen children aged 13-14 years over a period of 12 months. It was found results of experienced coughing (5.2%), S4 attack (1.6%), sleep disturbance due to wheezing (0.4%), severe wheeze limiting speech (0.8%), exercise-induced wheezing (8.2%), night cough (10.4%), and a total of studied children ever having had asthma was 9% (Beasley, 1998).

Another study of adolescent asthma in Northern Taiwan by Wu et al., (1998) found that from the total population of 158,330 boys and 154,760 girls, the prevalence of suspected asthma was 19.3% leading to eventual asthma diagnoses of 10.2%, which was somewhat higher in boys (11.6%) than in girls (8.2%). The highest prevalence in sub-areas was in metropolitan Taipei (13.0%) and the lowest was in Ilan (5.9%). The results indicated factors associated with asthma included living in areas with heavy air pollution, being a boy, higher parental education and being younger.

Wang, T., Yuan and Wang, L. (2012) also conducted a cross sectional random study which sampled 5754 subjects aged 18 and under, from elementary, junior and high schools in Southern Taiwan, found an association between metabolic factors and asthma. These findings indicated that abdominal fat, a high concentration of cholesterol, atopy risk (atopic allergy) and body mass index (BMI) have a high correlation with asthma but total cholesterol does not have a significant correlation with asthma. These assume that internal factors also contribute in incidence of asthma.

III.TREATMENTS AND PREVENTION

A variety of stepscan be taken to prevent and treat the occurrence of asthma attacks. The simple way is for those witha high risk of having an allergy to avoid the allergen. But if the person can't avoid the allergen, they can be treated by both pharmacological treatment and non-pharmacological treatment.

The pharmacological treatment includes the use of bronchodilators to relieve smooth muscle contraction, drugs to stabilize mast cells that release histamine, and anti-inflammatory drugs, including corticosteroids. Once the process of airway inflammation begins, treatment becomes more difficult because swelling and mucus plugging prevent inhaled medication from reaching the affected sites. Histamine, which stored in pulmonary mast cells, is a powerful stimulator of the smooth muscle of the airways, causing airway constriction (Cerny&Burton, 2001).

Philpott, Houghton & Luke (2010) and Krafczyk&Asplund (2011) recommended prevention for children or athletes with EIB by inhaling beta-2 agonists 15 min to 30 min before exercise. This should result in drops in FEV1(10% to 15%) after a 6 min to 8 min

exercise challenge and a positive response to beta-2 agonists medication. Furthermore, they recommended leukotriene inhibitors, inhaled corticosteroids and/or long-acting beta 2 agonists for optimal long-term disease control. However, they advised that children or athletes with asthma participating in sports should avoid overuse of short-acting beta 2 agonists.

The non-pharmacological treatment, avoiding the triggers like the allergens, environment and participating in sports with low minute ventilation (short burst of exercise such as football, baseball, wrestling, or sprinting) is advised for thosewhose asthma is getting worse.Immunotherapy may be also helpful as it makes people less sensitive to the allergens (Powers &Howley, 2012; Krafczyk&Asplund, 2011).

Exercise can be considered a non-pharmacological treatment for a person who has difficulty breathing, a particularly exercise that uses the aerobic system for energy. Aerobic exercise (AE) is beneficial to the function of the respiratory system and also increases aerobic capacity. Moreover, AE reduces the sensitivity of the respiratory tract to EIB and the associated drug doses required to treat asthma (Fanelli, Cabral, Neder, Martins &Carlvalho, 2007).

It was also suggested, for athletes with EIB need to adhere to three key rules. The first is pre-exercise warming up. This helps to reduce bronchoconstriction associated with EIB; the second is to use a mask. This is designed to limit cold air exposure during exercise in athletes with EIB.The third is to restrict dietary sodium intake for one to two weeks so as toreduce bronchoconstriction after exercise for asthmatic patients and EIB (Krafczyk&Asplund, 2011).

IV. EFFECTS OF EXERCISE AND RECOMMENDATIONS

3.1 Exercise-induced Bronchoconstriction (EIB)

Exercise-induced bronchoconstriction (EIB) is defined as a person who has difficulty breathing while participating in sport. It has long been known that physical activity may trigger symptoms in asthmatic children and named exercise induced asthma by John and his co-authors (John, Buston& Wharton, 1962). Recently, a name of exercise-induced bronchoconstriction was suggested by American Academy/College of Allergy Asthma and Immunology, and American Thoracic Society Clinical Practice Guideline to replace exercise-induced asthma because exercise is only one of many factors to trigg airway narrowing (Bonini&Palange, 2015). More than 10% of the general population and up to 90% of persons previously diagnosed with asthma have EIB. The prevalence of EIB in athletes ranges from 11-50%, although it approaches 90% in athletes with asthma (Parsons &Mastronarde,

2005).

The worst effects are seen during or after a workout, when the person experiences difficulty in breathing because of inflammation in the respiratory tract, i.e. exercise-induced bronchoconstriction (EIB) (Holzer, Anderson & Douglass, 2002; Parson, et al., 2007; Rundell, et al., 2001; Rundell&Slee, 2008). EIB is an indication of bronchial hyper-responsiveness (BHR). This is an acute respiratory tract condition resulting in a 10-20% reduction in FEV1. The concentration of histamine that stimulates a 20% fall in FEV1is defined as the PC20. That is accounted for in the devaluing after transformation of histamine. This process provokes exercise-induced bronchoconstriction (EIB) (Cockcroft, Berscheid, & Murdock, 1983; Crapo et al., 2000; Koh, Tee, Lasserson, & Irving, 2007; Weiler et al., 2007).

3.2 Physical Training Effects

Physical training programs improve cardiopulmonary fitness, as measured by increasing maximum oxygen uptake 5.4 ml/kg/min and maximum expiratory ventilation 6.0 l/minute. But, there is no effect on resting lung function or the number of days of wheeze caused by PA. PA does not cause wheezing in patients with asthma (Ram, Robinson, Black & Picot, 2005; Ram, Stewart &Peter, 2000).

Vieira et al., (2007) found that aerobic exercise with low and moderate intensity produces a decrease in airway inflammation and remodelling in a murine model of asthma, an increase of collagen 288%, elastic fibre 56%, smooth muscle 380% and epithelial 402%.

Sumartiningsih&Setiowati (2011) concluded that a two-month breaststroke swimming program, carried out three times a week, in which the subject completed a distance of 400 meters in each session significantly ($p = 0.000$) increased the peak flow rate (PFR) of air into the subject's lungs. These findings are consistent with Bemanian, Shirkhoda, Nakhjavani, &Mozafari (2009) who found that swimming programs three times a week for eight weeks significantly improved peak flow rates for 76 asthmatic girls.

Courteix, Obert, Lecoq, Gueno& Koch (1997) studied pre-pubertal females undertaking 12 hours a week of comprehensive swimming in a group of five swimmers, and two hours a week of various physical activities within the control group (11 females). The findings indicated that comprehensive swimming training in pre-pubertal girls significantly increased lung volumes and improved maximal expiratory flow-volume relationship, promoting an isotropic growth of the alveolar space.

Other than above-mentioned studies, some studies conducted for investigating PA training effect are listed in Table 2. The benefit of PA training toward asthma and EIB is obvious. The major of research is basically based on the effect of swimming exercise; it seems that swimming is the best choice for people with asthma to engage in PA.

Table 2. Summary of studies in benefitsof physical activity for asthma

Reference	Methods	Subject	Sample	Result
Fitch et al., 1976	3-5 times per week for five months; swimming	Children	56	Significant benefits in physical and emotional condition
Huang et al., 1989	Two month swimming program	Children	45	Significant improvement in all clinical variables, including symptoms, hospitalizations, and emergency-room visits, and school absenteeism compared with their previous medical history or to those of age-matched controls.
Courteix et al., 1997	Intensive swimming group for 12 hours a week, various physical activities in the control group for two hours a week	Female	16	Intensive swimming program for pre-pubertal girls resulted in increased lung volumes, improved maximal expiratory flow volume relationship, and promoting isotropic growth of the alveolar space.
Matsumoto et al., 1999	15 minutes swimming twice a day to six months		16	Increased aerobic capacity.
Wardell & Isbister, 2000	Swimming once a week for two years		73	Decreased morbidity and school absenteeism.
Ünal et al., 2004	Observation methods, before exercise testing and warm-up, Performed 3 times, best result was taken	Athletes	126	No significant difference for FVC, FEV1/FVC, MVV and IC among athletes with or without EIB.
Bermanian et al., 2009	Swimming 3 times per week for 8 weeks	Female	76	Significant improvement in peak flow rates in healthy and asthmatic patients
Wicher et al., 2010	Swimming programs twice a week, for three months		61	Improvement in bronchial hyper-responsiveness and elastic force to the chest.
Sumartiningsih &Setiowati, 2011	Pre-post test breaststroke swimming programs three-days per week for two months. Distance 400 meters.	Male 17 - 22 years	17	Increased peak expiratory flow rate.
Villa et al., 2011	Assessing muscle strength and endurance, cardiopulmonary exercise testing, inhaled corticosteroid consumption	Children	80	Children with SPA reduction in VO2max, and quadriceps endurance, but were not associated in between. Cardiopulmonary exercise and lower limb muscle endurance should be a priority during physical training.

3.3 Exercise Recommendation

Asthmatic patients need to improve their quality of life by enhancing the function of their respiratory and other bodily systems. Engaging in PA is important for people suffering fromasthma since it helps to ensure proper health.

American College of Sport Medicine [ACSM] (2014) suggested for general individual to engage PA prescription for individuals with asthma, as shown in Table 3.

Table 3. FITT Recommendation for individual with Asthma (ACSM, 2014)

Category	Prescription
Type of PA	Aerobic activities, walking, running, cycling, swimming
Frequency	At least 2 - 3 days per week
Intensity	At least 60% VO2peak or 80% of maximal walking speed from 6 minute walk test
Time	At least 20 - 30 minutes per day
Progression	Within a month, fitness may be improved by increasing the intensity to approximately 70% VO2peak, 40 minutes per day, and 5 day per week
Resistance exercise	Same as FITT recommended for general population

*FITT = Frequency, Intensity, Time and Type of exercise.

It seems true that people who suffer from asthma can participate in all types of exercise and physical activity, in the same way as people without asthma. Exercise isMedicine Australia (2014)recommended an exercise program for people with asthma in which focus on strength training (e.g. lifting weights), flexibility training and light (aerobic) PAwere focused. The program is shown in Table 4.

Table 4. Exercise program recommended for people with asthma (Exercise is Medicine Australia, 2014)

Type of training	Intensity	Frequency (times per week)	Duration
Aerobic (cardio) training	Low	5 or more sessions	At least 30 minutes
	High	3 or more sessions	At least 20 minutes
Strength training	70% of 1 RM*	2 or more sessions	2-3 sets of 8-12 repetitions

*RM = Repetition Maximum;1 RM corresponds to the maximum weight that can be lifted through the entire exercise movement on time.

For enhancing the cardiorespiratory system, muscle power and endurance, asthmatic children are also encouraged to engage in exercise programs (Kraemer, et al., (2011). Before setting out an exercise program for children with asthma, seeking advice from a medical doctor before is suggested (Table 5).

Table 5. Exercise program recommended for children with asthma (Kraemer, Fleck & Deschenes, 2011)

Activity	Attention or recommendation
—Pre Exercise	Warm up: Keep at low to moderate intensity Heart rate <75% predicted maximum for a few minutes Do not use intermittent sprinting Premedication: Take 200 μg salbutamol (albuterol) or equivalent via a large-volume spacer at least 10 minutes before starting warm-up Long-acting bronchodilator medication is needed
Preferred activities	Swimming, cycling and walking Aerobic activities (running and playing games) Competitive sports (soccer and basketball)
Monitoring	(1)Listen: heart rate, breathlessness, asthma (2)Rescue: medication should be available (3)Encourage: take an appropriate rest during high-intensity competitive sports
Contraindications	Fever and headache, especially respiratory infections.

Morton & Fitch (2011) in a position statement on exercise and asthmarecommended that asthmatics should structure their training according to five rules. First, the warm-up. This should progress from rhythmical low-level activity such as walking to jogging or other similar activities. Second, the aerobic segment. The training should start at a low level of intensity and gradually increase in intensity as the fitness level improves. The activity should utilize large muscle groups in a rhythmic fashion such as in walking, jogging, running, cycling, swimming, and various endurance game activities. Third, duration and frequency. Each part should last between 20 and 60 minutes and be carried out 3-5 times a week. Fourth, exercise loading. The training should be from low level continuous to medium or high level depending on the condition of the athlete. Fifth, warm-down. Every activity should be completed by cooling down, whereby heartbeat is reduced by 20 beats or back to pre-exercise level.

V. CONCLUSION

Asthma is a common chronic disease caused by airway inflammation and hyper-reactivity of the smooth muscle of the respiratory tract. If properly prepared, the asthmatic personis able to enjoy exercise which will preventa gradual worsening of their physical fitness and quality of life. Under a well-controlled program, participation in any levels of competitive sports is possible. In addition to pre-exercise warm-up and post-exercise warm-down periods, a mask can be applied to prevent the dry and cold being inhaled. It is desirable to control the intensity of exercise to be under the anaerobic threshold. In addition, to swimmingin a low chlorine pool, resistance exercise and flexibility exercise are one of the best choices for asthmatics. Ever though application of beta-2 agonists 15-30 minutes before exercise is useful, precaution should be taken since its tapering effects induced by long-term application. Finally, seeking advice from a medical doctor before any exercise training protocol is important.

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