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**EXERCISE-INDUCED BRONCHOCONSTRICTION:  
STIMULATING FACTORS, MECHANISMS AND TEST PROTOCOLS****Lyubomyr VOVKANYCH***Lviv State University of Physical Culture, Lviv, Ukraine, e-mail: lsvovkanych@gmail.com***БРОНХОСПАЗМ, СТИМУЛЬОВАНИЙ ФІЗИЧНИМИ НАВАНТАЖЕННЯМИ: ПРИЧИННИ ВИНИКНЕННЯ, МЕХАНІЗМИ РОЗВИТКУ ТА ПРОТОКОЛИ ДОСЛІДЖЕННЯ. Любомир ВОВКАНИЧ.**  
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**Анотація.** Огляд літератури спрямовано на аналіз вірогідних причин та механізмів розвитку стимульованого фізичними навантаженнями бронхоспазму (СФНБ) у спортсменів та методів діагностики цього явища із використанням різних протоколів тестування. Установлено, що явище СФНБ можна пояснити з погляду термічної (унаслідок явищ вазоконстрикції та гіперемії) та осмотичної (підвищення тонузу гладкої мускулатури після підвищення осмотичності у дихальних шляхах) теорій. Явище СФНБ діагностують за зниженням об'єму форсованого видиху за 1 с та пікової об'ємної швидкості видиху. Для стимуляції СФНБ застосовують тестові протоколи з використанням довільної гіпервентиляції, інтенсивних фізичних навантажень чи вдихання гіперосмолярних препаратів.

**Ключові слова:** фізичні вправи, бронхоспазм, спорт.**БРОНХОСПАЗМ, СТИМУЛИРУЕМЫЙ  
ФИЗИЧЕСКИМИ НАГРУЗКАМИ:  
ПРИЧИНЫ ВОЗНИКНОВЕНИЯ,  
МЕХАНИЗМЫ РАЗВИТИЯ  
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**Аннотация.** Обзор литературы направлен на анализ вероятных причин и механизмов возникновения стимулируемого физическими нагрузками бронхоспазма (СФНБ) у спортсменов и методов диагностики этого явления с использованием разных протоколов тестирования. Установлено, что явление СФНБ можно объяснить с точки зрения термической (вследствии явлений вазоконстрикции и гиперемии) и осмотической (повышение тонузу гладкой мускулатуры после увеличения осмотичности в дыхательных путях) теорий. Явление СФНБ диагностируют по снижению объема форсированного выдоха за 1 с и пиковой объемной скорости выдоха. Для стимуляции СФНБ применяют тестовые протоколы с использованием произвольной гипервентиляции, интенсивных физических нагрузок или вдыхания гиперосмолярных препаратов.

**Ключевые слова:** физические упражнения, бронхоспазм, спорт.**EXERCISE-INDUCED  
BRONCHOCONSTRICTION:  
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**Summary.** The aim of the present review was to analyze the possible stimulus and mechanisms of the exercise-induced bronchoconstriction (EIB) in athletes and the methods of this phenomenon diagnostic on the basis of different test protocols. It was shown that EIB can be explained by the thermal (as the result of vasoconstriction-hyperaemia) and osmotic (increase in osmolarity in airways with the following smooth muscles contraction) theories. The EIB is diagnosed on the basis of reduction in forced expiratory volume in 1 s or peak expiratory flow rate. The test protocols with voluntary hyperpnoea, intensive physical loadings and aerosols of hyperosmolar agents inhalation has been used for EIB stimulation.

**Key words:** exercises, bronchoconstriction, sport.

**Scientific problem.** There are no doubts that in many sports respiratory capacity of athletes play the important role in the high sport achievements. Such importance can be supported by many observations showed the adaptive changes in the respiratory system of the athletes engaged in various sports [27, 37, 41]. The significant improvement in the pulmonary functions have been found in endurance trained athletes: swimmers [37, 49], basketball and water polo players, rowers [41], cyclists, middle and long distance runners [27], orienteers [53]. The adaptive changes most commonly

results in the increase of some pulmonary function tests (lung volumes and capacities, forced expiratory volume in one second, peak expiratory flow etc.) [2, 11, 37, 41]. Some studies have suggested the significant positive relationship between aerobic capacity and pulmonary function tests [11, 17, 24, 27]. Some authors have suggested that respiratory system could be an exercise limiting factor in the endurance events [12, 35]. At the same time, the endurance athlete is at risk of bronchoconstriction development. This risk is increased by repeated exposure to environmental factors such as cold air (winter athletes, football players, orienteers, rugby players etc.), organic chlorine compounds (water athletes), pollution (cyclists) [14]. Some studies have suggested that exercise-induced bronchoconstriction (EIB) is an early manifestation of airway hyperresponsiveness [6, 10] and asthma development. The important role of repetitive airway injury during sport activity is supported by the observations of normal airways responsiveness after the season [30] or sport career [18] end. It is reasonable to assume that the bronchoconstriction development may cause the decrease in aerobic capacity, sport performance and form the basis for some pathological changes in respiratory system. That is why the study of the EIB in recent years has received increased attention from researchers involved in physiology and sport physiology.

The primary **aim** of the present study was to analyze the possible stimulating factors and mechanisms of the exercise-induced bronchoconstriction in athletes and the methods of this phenomenon diagnostic on the basis of different test protocols.

**Materials and methods.** In order to the primary aim achievement the retrospective literature review has been conducted.

**Results and discussion.** The discussion of the mechanism of EIB has received considerable attention in physiological and medical literature. In recent studies related to the topic, the EIB is determined as the increase in airway resistance that follows vigorous exercise that is measured as a reduction in lung function after an exercise test or natural exercise [6, 8, 21]. In the early investigations the correlating between the exercise load and increase of bronchial hyperresponsiveness among swimmers has been shown [6, 52]. After it many authors reported occurrence of bronchial hyperresponsiveness and asthma among cross-country skiers, winter sport athletes, elite endurance summer athletes, swimmers [6, 9, 16, 28, 29, 34, 45]. The EIB was also found in the study of football [33, 36, 42], rugby [22], basketball and water polo [33] athletes.

Exercise-induced bronchospasm is common among asthmatic children. After vigorous exercise, about 80 percent of them develop significant bronchoconstriction. However EIB can be seen in healthy children as well as elite athletes [38]. The exercise-induced bronchospasm has been reported in high percent of young sportsmen [4, 15, 20, 32, 33, 48, 50]. Some authors argue that exercise-induced bronchospasm should not be confused with the chronic inflammatory disease [31].

There are two main theories of the mechanism of EIB [5, 6, 14]. The thermal theory of EIB suggests that the airway cooling cause a vasoconstriction of the vessels of the bronchial circulation. As it is well known, the physical activity increases minute ventilation, proportional to the intensity of the physical activity. This causes increased water and heat loss through the respiration. The airways are cooled resulting in reflex parasympathetic nerve stimulation causing bronchoconstriction and vasoconstriction of bronchial venules to conserve heat. After the exercise finish, the rebound vasodilatation happens, results in smooth muscle constriction, reducing the size of the bronchial lumen with increased airways resistance [14]. These vascular events are likely to be relevant to winter athletes exercising at high levels of ventilation under cold conditions [6].

The thermal theory of EIB does not account for all observations on exercise-induced bronchospasm. For example, EIB is developed under the hot ( $>36^{\circ}\text{C}$ ) and dry air breathing during exercise, but it is inhibited or completely prevented when the inspired air at body temperature and fully saturated with water [6]. These observations led to the osmotic theory of EIB. According to this theory, the increased minute ventilation during the exercise performance caused the increased water loss by evaporation which leads to a transient increase in the concentration of ions in the airway surface liquid with a consequent increase in osmolarity [6, 14]. The water loss from the bronchial mucosa induces an efflux of intracellular water to the extracellular space [7] causing an intracellular increase in ion concentration [19]. This process result in eicosanoids [26] and histamine release and

cause bronchoconstriction [14]. It is suggested that effect of cold air is partially caused by low content of water and drying of the respiratory mucosa [7]. There are many sources for the EIB mediators. Among them are the mast cells, eosinophils, sensory nerves and epithelial cells [6]. The mast cell is considered to be the major source of mediators of bronchoconstriction, such as prostaglandin D<sub>2</sub>, leukotriene C<sub>4</sub> and histamine. Eosinophils are another source of cysteinyl-LTs [39] and sputum eosinophilia is common in bronchoconstriction [44]. These cell types release mediators in response to hyperosmolarity [39, 40]. As suggested by Carlsen K-H. (2012) [14], the regular maximal and near-maximal exercises along with cold and dry air, chlorine compounds or environmental pollution, may cause repeated (continuous) epithelial damage and increased airways inflammation. The airways inflammation and increased parasympathetic activity in endurance athletes leads to development of bronchial hyperresponsiveness and asthma symptoms [14].

It is thus clear the importance of environmental conditions in which athletes are training, for the respiratory health. Cold environment, pollution and harmful chemicals in the air increase the risk for asthma development. Trainings and competitions should not be carried out in too cold environments, and endurance sports should not be carried out in areas with high air pollution [14].

Hence, the EIB influences sports activities in children, adolescents and adults. In order to eliminate the risk of bronchoconstriction development and enable optimal choice of treatment, an accurate assessment of EIB is important [47]. Usually the EIB is diagnosed on the basis of reduction in forced expiratory volume in 1 s (FEV<sub>1</sub>) or peak expiratory flow rate (PEFR) of 10–15% from the preexercise value within 20–30 min of exercise [3, 6, 47, 50]. Because several studies [47] have shown that bronchoconstriction occurs soon after the exercise, the lung function usually was measured before and 1, 3, 6, 10 and 15 (or 2, 5, 10, 15 and 30) minutes after the test [4, 20, 23, 46].

The voluntary hyperpnoea with dry air has also been used for identify EIB [43]. In that case the ventilation volume must exceed 30–40 L per min [6] or up to 30xFEV<sub>1</sub> during the first 30 s and sustained for 6–8 min [25]. When a physical loadings are used instead of voluntary hyperpnoea, the ventilation level must reach more than 17,5 x FEV<sub>1</sub> (50% of maximum voluntary ventilation) and the heart rate – 80% of predicted maximum in the first 2 min of the exercise. This intensity needs to be sustained for 6 min in young children and 8 min in adolescents and adults [1, 6, 13, 20, 48]. If the ventilation increases too slowly, refractoriness to the stimulus at higher ventilations is observed [51]. Some authors reported that 20 min warm-up at submaximal intensity or 30 s repeated sprints cause refractoriness to following vigorous exercise [6]. In order to increase the airway surface osmolarity the aerosols of hyperosmolar agents (4,5% saline and mannitol dry powder) have also been used [6]. This test is preferred over exercise in clinical practice.

**Conclusions and research prospects.** Many observations have shown that EIB is caused by heat loss and water loss through respiration during exercise. The thermal theory proposes that EIB is a result of vasoconstriction during exercise followed by rapid rewarming and hyperaemia after the end of exercise. The osmotic theory proposes that water loss induces an increase in osmolarity in the airways, which causes the release of mediators that cause bronchial smooth muscle to contract. The frequently repeated increase of ventilation may cause the development of asthma and bronchial hyperresponsiveness in the competing elite athletes. The EIB is diagnosed on the basis of reduction in forced expiratory volume in 1 s (FEV<sub>1</sub>) or peak expiratory flow rate (PEFR). The test protocols with voluntary hyperpnoea with dry air, the intensive physical loadings and aerosols of hyperosmolar agents inhalation are commonly used in the diagnosis of EIB.

Our future studies should reveal the frequency of EIB occurrence in the training process of young football players.

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