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Study of exercise induced bronchospasm by various loading tests

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In 378 children affected by asthma and 87 healthy children, physical loading was carried out by three kinds of test, *viz.* free running, stairstep test or skipping, and bicycle ergometry. In 32% of healthy children physical exercise led to improved respiratory function, while this value was only 7% in asthmatics. An improvement in respiratory function exceeding 20%, i.e. appreciable bronchial dilatation, never occurred in asthma patients. The bronchospasm of healthy children showed no consistent time course, in asthmatics it was most pronounced three minutes after exercise. Exercise induced bronchospasm occurred most frequently after free running, least frequently after ergometric loading. The stairstep test and skipping provoked exercise induced bronchospasm in a nearly identical proportion. Severity of exercise induced bronchospasm exhibited a similar distribution. In addition to cases with a positive response to running test, some of the other methods revealed further 5—6% of cases. Free running is the most suitable method for demonstration of exercise induced bronchospasm, ergometric loading appears the least sensitive test in this respect. By application of three loading tests exercise induced bronchospasm could be demonstrated in 52% of paediatric asthma patients.

Physical exercise provokes dyspnoea, sometimes an asthmatic attack in a proportion of asthma patients. The phenomenon has been called exercise induced asthma (EIA) or exercise induced bronchospasm (EIB). All methods demonstrating respiratory obstruction or hyperinflation are suitable tools in diagnosis.

There is no unanimity about the percentual decrease of respiratory function tests as a criterion of EIB. Some authors take a 10% decrease in PEFR or FEV_1 as sufficient [1, 19, 31, 32], others [4, 5, 31] take 15% and some [9, 12] think that at least 20% is necessary for the diagnosis of EIB. In evaluating airway resistance or volume/flow curves, usually larger changes are regarded as a proof of EIB [4, 16]. Quite obviously, the choice of the critical value has an impact on the incidence of EIB among asthma patients. In addition, the type of loading test also influences the frequency of EIB [1, 3, 7, 33], and duration and magnitude of the exercise load also alter the results. The most pronounced bronchospasm can be elicited by an exercise corresponding to 60—80% of maximum physical performance, applied for six minutes, leading in children to a heart rate of about 180 per minute [19, 20].

The complaints experienced by the patients and the severity of EIB are

TABLE I

Increase in lung function values after exercise

	0–10%	11–20%	More than 20%	All
Healthy	12	8	11	31
Asthmatic	17	10	0	27

TABLE II

Degree of decrease	Number of subjects	Percentage
0–11%	41	42%
11–15%	19	20%
16–20%	6	6%
All	66	

TABLE III

Lowest lung function values and time after exercise in healthy and asthmatic children

	Time in minutes					All
	3	5	10	15	20	
Asthmatics	226	97	35	20	Ø	378
Healthy	26	23	27	12	9	97

TABLE IV

Number of patients with 11—20% decrease in lung function

Running	6
Skipping	8
Stairsteps	5
Ergometer	6
All	25

TABLE V

Number of patients experiencing asthmatic attack during exercise

Free running	9
Skipping	5
Stairsteps	4
Ergometer	4
All	22

TABLE VI

Frequency of EIB after various forms of physical loading

	EIB positive	EIB negative	All patients
Free running	151 (40%)	227 (60%)	378
Skipping	61 (27%)	169 (73%)	230
Stairsteps	50 (25%)	151 (75%)	201
Ergometer	75 (21%)	286 (79%)	361
Total	195 (52%)	183 (48%)	378

not necessarily related. There is a wide scatter in the literature in respect of the incidence of EIB. Comparison of the different loading methods has usually been performed in a small number of patients and not always in the same persons [1, 10, 17, 18, 19, 26].

The present study has been aimed at comparing the effect of various loading methods on the incidence of EIB. Natural exercise patterns were preferred.

PATIENTS

Exercise tests carried out by three methods were performed in 97 children free from atopic disease and with a negative family history of atopy, and in 378 patients affected by asthma. The non-asthmatic persons had a mean age of 10.6 ± 3.5 years, their mean height was 40 ± 18 percentile, there were 60 boys and 37 girls. The corresponding values for the asthmatic children were 9.4 ± 2.9 years, 39 ± 16 percentile, 248 boys and 130 girls.

METHODS

Three types of exercise were applied in randomised sequence, free running, running on stairsteps or skipping, and ergometric load. Between the individual loadings an interval of 2 hours was prescribed. The pulmonary functions were tested in an open system digital device, type Medicor SP 21. Peak expiratory flow rate (PEFR), forced expiratory volume expired during half second (FEV_{05}), and one second (FEV_1), forced vital capacity (FVC) were determined before and 3, 5, 10, 15 and 20 minutes after exercise. The magnitude of the 6-minute load was chosen so as to attain a heart rate exceeding 170/min by the end of the second minute of the test. A decrease in any of the above mentioned parameters exceeding 20% was regarded as a criterion of bronchospasm.

RESULTS

In 31 out of the 97 healthy children (32%), exercise induced an increase in respiratory function values. In 11 (11%) the increase exceeded 20%. In none of the 378 asthmatic children was an increase exceeding 20% observed, in 27 asthmatic children was improvement in lung function observed after exercise (7%).

In 66 out of 97 healthy children the respiratory function tests exhibited a decrease after exercise; the decrease was less than 20% in all of them. In healthy children the decrease showed no characteristic pattern as a function of time. The lowest values were evenly distributed among 3, 5, 10, 15 and 20 minutes after the load. The various loading methods did not lead to different results in healthy children.

TABLE VII

Severity of EIB after various forms of physical loading

	0—10%	11—20%	21—30%	31—40%	40%—	All
Free running	36 (10%)	191 (50%)	73 (19%)	37 (10%)	41 (11%)	378
Skipping	27 (12%)	142 (62%)	35 (15%)	15 (6%)	11 (5%)	230
Stairsteps	22 (11%)	129 (64%)	32 (16%)	8 (4%)	10 (5%)	201
Ergometer	47 (13%)	239 (66%)	52 (14%)	17 (5%)	6 (2%)	361

The exercise was well tolerated by the great majority of asthmatic children. An asthmatic attack developed in 22 (6%) patients; in two of them the exercise had to be interrupted.

Physical examination revealed signs of bronchospasm in 53 patients (14%). In 5 patients (1%) a pronounced inflation of the thorax developed. 58 patients (15%) needed application of bronchodilator spray, 2 patients experienced dyspnoea, cyanosis and tachycardia during exercise. The symptoms soon subsided on rest and administration of aminophylline.

We investigated the rate of EIB elicited by any method apart from free running. EIB could be provoked by bicycle ergometer only in 18 patients (5%), by stairstep test only in 12 (6%) and by skipping only in 14 (6%).

Ambient temperature and relative humidity were identical during ergometric loading and skipping (mean, 25.7°C and 43.7%). During the stairstep test, the mean temperature was 25°C, relative humidity, 55.6%. During free running the mean temperature was 21.9°C and relative humidity was 59.8%. The maximum heart rate induced by the loads did not differ significantly: free running, 197/min; skipping, 193/min; stairstep test, 198/min; ergometric loading, 194/min.

The severity of EIB was also estimated; the results are shown in Table VII.

DISCUSSION

The reaction of asthmatic patients to physical exertion differs from that of healthy persons. In a proportion of asthmatics, exercise induces bronchospasm. If obstruction occurs in healthy individuals the decrease of PEFR or FEV_1 is smaller than 10—15% of the initial value. A significant difference in respiratory function was found between asthmatic and healthy persons 3, 5, 10, 15 and 20 minutes after exercise [5, 9, 11, 13, 14, 19, 28, 33]. Burr et al [11] observed a decrease in PEFR of less than 10% in 92% and one less than 15% in 98% of healthy children, while the decrease in FEV_1 exceeded 15% in 7% of healthy children. Silverman and Anderson [36] found that the PEFR was never

depressed by more than 15% in healthy individuals, others could not demonstrate any significant reduction of any lung function in healthy persons subjected to exercise [15, 28, 30].

In the present study, 20% of healthy children exhibited a 11—15% reduction of respiratory function and in 6% was the decrease between 16 and 20%. No healthy child showed a decrease exceeding 20%.

Field et al [17] found improved respiratory functions after exercise in an appreciable proportion of healthy persons, and 11% of our healthy children displayed an increase in lung function higher than 20% after exercise. Such an improvement has never been observed in asthmatics. The improvement occurring in healthy subjects is due to bronchodilatation induced by the sympathetic effect of physical exertion. In asthmatics the bronchospasm shows a characteristic time course: it attains a maximum 3—5 minutes after exercise and spontaneously abates within 15—20 minutes [2, 3, 13, 14, 20, 21, 25, 26, 27]. Our results revealed no characteristics in the bronchospasm induced by exercise in healthy children, while in asthma patients it was the most pronounced 3 minutes after exercise. The bronchospasm resolved spontaneously in all healthy subjects.

In healthy children the type of physical load had no specific effect on the changes induced by exercise. The bronchospasm of asthmatic patients provoked by exercise abated spontaneously in the overwhelming majority of cases [3, 13, 16, 20, 21]. 15% of the patients needed bronchodilator drugs after exercise. In healthy children no physical signs of bronchospasm were encountered while in 15% of asthmatics such signs could be demonstrated after physical exercise.

Two patients felt distinctly unwell after exercise. Still, physical loading is a substantially safe diagnostic procedure in childhood [14, 26].

The data on the frequency of EIB are conflicting; the values suggested vary between 14 and 100%. Jones et al [26, 27] regard the EIB so characteristic of asthma that in their opinion its absence should prompt one to reconsider the diagnosis. Comparative studies have shown different frequencies of EIB after various loads. The highest frequency was reported after free running, this was followed by treadmill, stairstep and ergometric tests, the lowest incidence was observed after swimming; other authors did not find differences if the experimental conditions were fixed.

In the present study, free running induced EIB with the highest incidence (40%), the lowest incidence was seen after ergometer loading (21%), and stairstep (25%) and skipping (27%) were of intermediary effect. Application of several loading tests increases the probability of diagnosing EIB [21]. In our patients, the methods apart from free running increased the incidence of EIB by an additional 5—6%. In children ergometric loading was the least suitable for the demonstration of EIB. Even stairstep running and skipping, meth-

ods necessitating no special installation, were more suitable.

The severity of EIB may be characterized by the decrease in lung function values, thereby EIB may be classified as mild, moderate or severe [13]. The principles of classification are rather different with individual authors. For instance, Cropp [13] regards a 25—40% decrease in PEFR as mild, 41—60% as moderate, and a decrease exceeding 60% as severe. According to Pierson and Bierman [30] a fall smaller than 10% is the criterion of a mild EIB, 10—25% is moderate and a value larger than 25% indicates severe EIB. Eggleston and Guerrant [16] demonstrated moderate or severe EIB in three fifth of patients, while Cropp [13] found mild, moderate and severe reductions in equal proportions. Severe EIB is more frequent in boys than in girls. In our own material the various degrees of severity were observed in nearly equal proportions; severe EIB occurred in 18% of the patients, moderate in 15% and mild in 21%. Severe EIB was induced most frequently by free running, least frequently by ergometer loading, an intermediate frequency was seen after stairstep test and skipping.

References

1. Anderson SD, Connolly NM, Godfrey S: Comparison of bronchoconstriction induced by cycling and running. Thorax 26:396, 1971
2. Anderson SD, McEvoy JDS, Bianco S: Changes in Lung Volumes and Airway Resistance after Exercise in Asthmatic Subjects. Am Rev Respir Dis 106:30, 1972
3. Anderson SD, Silverman M, König P, Godfrey S: Exercise-induced asthma. Br J Dis Chest 69:1, 1975
4. Bierman CW, Pierson WE, Shapiro GG: Exercise-induced asthma. JAMA 234:295, 1975
5. Bierman CW, Kawabori I, Pierson WE: Incidence of exercise-induced asthma in children. Pediatrics 56 Suppl: 847, 1975
6. Bierman CW, Pierson WE: Summary. Pediatrics 56 Suppl: 850, 1975
7. Böszörményi Nagy Gy, Herjavecz I: A fizikai terheléssel, acetilkolin és specifikus allergén inhalációjával kapcsolatos bronchiális hiperreactivitás összefüggése asthma bronchialéban. Pneumonol Hung 35:256, 1982
8. Buckley JM, Souhrada JF: A comparison of pulmonary function tests in detecting exercise-induced bronchoconstriction. Pediatrics 56 Suppl: 883, 1975
9. Bundgaard A: Incidence of exercise-induced asthma in adult asthmatics. Allergy 36:23, 1981
10. Bundgaard A, Thorsten Schmidt A, Hansen I, Halkjaer-Kristensen J, Bloch I: Exercise-induced asthma after swimming and bicycle exercise. Eur J Respir Dis 63:245, 1982
11. Burr ML, Eldridge BA, Borysiewicz LK: Peak expiratory flow rates before and after exercise in schoolchildren. Arch Dis Child 49:923, 1974
12. Cropp GJA: Relative sensitivity of different pulmonary function tests in the evaluation of exercise-induced asthma. Pediatrics 56 Suppl: 860, 1975
13. Cropp GJA: Grading, time course, and incidence of exercise-induced airway obstruction and hyperinflation in asthmatic children. Pediatrics 56 Suppl: 868, 1975
14. Cropp GJA: The exercise bronchoprovocation test: Standardization of procedures and evaluation of response. J Allergy Clin Immunol 64:627, 1979
15. Deal EC, McFadden ER, Ingram RH, Breslin FJ, Jaeger JJ: Airway responsiveness to cold air and hyperpnea in normal subjects and in those with hay fever and asthma. Am Rev Respir Dis 121:621, 1980
16. Eggleston PA, Guerrant JI: A standardized method of evaluating exercise-induced asthma. J Allergy Clin Immunol 58:414, 1976
17. Field J, Allergra J, Tautlein J, Gillin M, Zelis R: Evaluation of exercise-induced bronchospasm in the adult

asthmatic. J Allergy Clin Immunol 58: 575, 1976
18. Fisher HK, Holton P, Buxton RSTJ, Nadel JA: Resistance to breathing during exercise-induced asthma attacks. Am Rev Respir Dis 101:885, 1970
19. Fitch KD, Morton AR: Specificity of exercise in exercise-induced asthma. Br Med J 4:577, 1971
20. Godfrey S, Silverman M, Anderson SD: Problems of interpreting exercise-induced asthma. J Allergy Clin Immunol 52:199, 1973
21. Godfrey S: Exercise-induced asthma — clinilcal physiological, and therapeuti impications. J Allergy Clin Immunol 56:1, 1975
22. Godfrey S: Exercise-induced asthma. Arch Dis Child 58:1, 1983
23. Hofmann D, Wonne R, Linn M, Glasemann H: Über die Häufigkeit des Anstrengungsasthmas (Exercise Induced Asthma, EIA) im Kindesalter. Monatschr Kinderheilkd 130:91, 1982
24. Irnell L, Swartling S: Maximal expiratory flow at rest and during muscular work in patients with bronchial asthma. Scand J Resp Dis 47:103, 1966
25. Jones RS, Buston MH, Wharton MJ: The effect of exercise on ventilatory function in the child with asthma. Br J Dis Chest 56:78, 1962
26. Jones RS, Wharton MJ, Buston MH: The place of physical exercise and bronchodilatator drugs in the assessment of the asthmatic child. Arch Dis Child 38:539, 1963
27. Kattan M, Keens TG, Mellis CM, Levison H: The response to exercise in normal and asthmatic children. J Pediatr 92:718, 1978
28. Kawabori I, Pierson WE, Conquest LI, Bierman W: Incidence of exercise-induced asthma in children. J Allergy Clin Immunol 58:447, 1976
29. Lefcoe NM, Carter RP, Dildar A: Postexercise bronchoconstriction in normal subjects and asthmatics. Amer Rev Resp Dis 104:562, 1971
30. Pierson WE, Bierman WC: Free running test for exercise-induced bronchospasm. Pediatrics 56 (suppl): 890, 1975
31. Schachter EN, Kreisman H, Littuer M, Beck GJ, Voncken F: Airway responses to exercise in mild asthmatics. J Allergy Clin Immunol 61:390, 1978
32. Schachter EN, Rimar S, Littuer BAM, Beck GJ, Bouhuys A: Airway reactivity and exercise in healthy subjects. Chest 81:461, 1982
33. Silverman M, Anderson SD: Standardization of exercise tests in asthmatic children. Arch Dis Child 47:882, 1972

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