Effects of physical training on hormonal responses to exercise in asthmatic children

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SUMMARY A 4-month period of physical training increased the physical working capacity of 16 asthmatic children (aged between 9.3 and 13.6 years) by a mean of 11 %. The increase was greater in boys and was negatively correlated with pretraining capacity. Urinary excretion of adrenaline, measured during a submaximal exercise test, decreased during the training period; the decrease was correlated with the increase in working capacity. Before the training period, exercise induced an increase in the plasma cortisol level; no increase was evident after training. In contrast, the training did not affect the exercise-induced increase in the plasma growth hormone level.

Training programmes have been evaluated (Geubelle *et al.*, 1971; Vavra *et al.*, 1971; Fitch *et al.*, 1976) for improving the poor physical fitness of asthmatic children (Fowler and Gardner, 1963; Godfrey, 1974). The disturbing effect of exercise-induced bronchospasm (Jones *et al.*, 1962; Bierman *et al.*, 1975) can be avoided by swimming training (Fitch *et al.*, 1976) or by dividing the training into short bursts of activity (Strick, 1969). Exercise stimulates the secretion of several hormones (Felig and Wahren, 1975) and training may modify the responses (Hartley *et al.*, 1972a). Therefore, we set out to study whether the exercise-induced responses of adrenaline, cortisol, and growth hormone (GH) would change during a training programme for asthmatic children.

Subjects

Eight boys and 8 girls (see Table for clinical data) consented (with the approval of their parents) to participate in the exercise tests and the training programme. All the children had bronchial asthma diagnosed more than 4 years earlier. Five children had a history of exercise-induced asthma; all of them, and 2 others, used sodium chromoglycate inhalations. No oral corticosteroids were used, but

2 children took daily inhalations of beclomethasone. Sympathomimetic medication, if any, was stopped at least 10 days before the tests. No healthy child participated in the programme.

Training programme

During 4 winter months the children were offered a total of 31 sessions of training, on Mondays and Thursdays, after school in a gymnasium under the supervision of a physiotherapist. The children used a mean of 19 sessions, with a range of 12 to 28. The 60-min training session consisted of 10 min of warming up with light gymnastics, 5 min of breathing exercises, a 20-min period of four 1-min bursts of maximal activity (skipping-rope, fast jumping, stepping chair exercises, etc.), interrupted by rest and/or light gymnastics, 5 min of light exercises (rings, parallel bars, etc.), and 20 min of ball games or other sports (football, table tennis, relay race, etc.). In the rare case of exercise-induced bronchospasm the child took a break and did light breathing exercises until the attack ceased. No sympathomimetic drugs were needed.

Methods

The children were tested within 2 weeks before the beginning (pretraining test) and within 2 weeks after the end (post-training test) of the training programme. In the morning an indwelling venous catheter was introduced for collecting blood samples. Just before the test, the child urinated and a basal blood sample

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was taken. Then samples were taken half-hourly for 2 hours, a 2-hour urine sample was collected, and tetracosactide (S-Cortrophin, Organon, Netherlands), 0.15 mg/m^2 , was given IV for a 2-hour ACTH test (Leisti and Perheentupa, 1978a). Blood samples were taken without stasis into heparinised Pyrex tubes, which were placed immediately in an ice-water bath. Plasma was separated after the last sample. Urine was collected in glass containers, which included 5 ml HCl, 6 mol/l. Both plasma and urine samples were stored in a freezer. All samples from the same child were assayed in the same run at the end of the programme.

Submaximal bicycle ergometer tests were modified slightly from the scheme proposed by Sjöstrand (1967). The three 4-min loads were chosen individually in order to achieve the pulse rates of 80–90, 100–120, and 150–160 beats/min, respectively. In the postexercise tests the same loads were used. Then the physical working capacity for the pulse rate 180 beats/min was determined graphically. The result was expressed in watts per m^2 of surface area ($1 \text{ W} = 6.12 \text{ kpm/min}$). We prefer correction by surface area to correction by weight or by height, because, according to our calculations made on the data of Adams *et al.* (1961), the effects of age and sex are both best corrected by this method in this age group.

Peak expiratory flow rate (PEFR) (Kattan *et al.*, 1978) was determined immediately before the exercise test, and again 8–10 min after the end of the test. The highest value achieved in three attempts was used for calculation of the percentage change from the pre-exercise value. Plasma cortisol was determined with a fluorometric method (Leisti and Perheentupa, 1978a), plasma GH with a radioimmunoassay (Leisti and Perheentupa, 1978b), and urinary adrenaline with a fluorometric method (Crout, 1961). Student's 2-tailed *t* test (for differences between boys and girls), Student's paired *t* test (for differences between pre- and post-training values), and correlation coefficients were used for evaluating the results.

Results

Effect of training on working capacity. Working capacity was increased by a mean of 11% (15% in the boys, 10% in the girls; see Table). The increase was not correlated with the total number of participations in the training programme ($r = -0.16$), but was clearly negatively correlated with the pre-training working capacity ($r = -0.54$, $P < 0.05$).

Effect of training on exercise-induced change in PEFR. A decrease of more than 15% was seen in

two children during the pretraining test, and in one more child in the post-training test. Training had no clear effect on the submaximal exercise-induced change in PEFR, and the individual patterns seemed to remain consistent (Table).

Effect of training on exercise-induced hormonal response. The mean urinary adrenaline response decreased by 46% during the training period (Table). The effect was clearer in boys (55%) than in girls (29%); girls also had lower mean responses in both pre- and post-training tests. The decrease in adrenaline response correlated significantly with the increase in working capacity (Fig. 1).

Exercise induced an increase in the mean plasma cortisol level in the pretraining test, but this was no longer evident in the post-training test (Fig. 2). However, maximum cortisol levels were not significantly lower in the postexercise tests. Boys had higher maximum cortisol levels in the pretraining tests than girls, but after training there was no difference. Training had no effect on the ACTH test response (Table).

Exercise induced an increase in the mean plasma GH level in both tests (Fig. 2). Training had no effect on the GH response.

No correlations were detected between the pre-training working capacity and pretraining hormonal responses, or between the same variables measured after the training period. The plasma lactate response was not altered by the training, but boys had higher mean values in the pretraining test than girls (Table).

Fig. 1 Change in the working capacity related to change in urinary adrenaline excretion during a 4-month course of physical training in 14 children with bronchial asthma.

Conversion: SI to traditional units—adrenaline: $1 \text{ nmol} \approx 0.18 \text{ } \mu\text{g}$.

Table Clinical data and responses of 16 asthmatic children to submaximal bicycle ergometer test before and after a 4-month training period

Case	Age (years)	Continuing treatment	Exercise-induced variables				ACTH test										
			Working capacity (W/m ²)		Change in PEFR (%)	Maximum plasma lactate (mmol/l)		Urinary adrenaline 2-h excretion nmol/(m ² per h)		Maximum plasma GH (μU/l)		Maximum plasma cortisol (nmol/l)		Plasma cortisol 2-h level (nmol/l)			
			Before	After		Before	After	Before	After	Before	After	Before	After	Before	After		
Boys																	
1	13.6	SC, BI	110	103	0	4	2.2	2.3	2.7	1.9	42	24	770	300	990	900	
2	13.4	—	54	58	3	—1	2.3	2.2	2.9	1.8	12	16	660	570	1460	1260	
3	12.6	—	56	72	—8	—8	1.7	1.8	5.8	1.5	<1	<1	980	510	1560	1380	
4	11.3	SC	79	77	7	—2	2.4	2.8	4.5	2.3	4	21	470	230	1060	920	
5	10.8	SC	66	81	7	30	1.7	2.5	—	—	40	22	470	650	910	880	
6	10.2	SC	48	72	—4	—51	1.8	2.0	5.6	1.7	61	16	950	1270	950	1350	
7	9.6	—	78	91	—4	—7	2.1	2.1	1.0	1.2	23	7	280	360	800	790	
8	9.3	—	54	66	—16	—28	2.8	2.2	—	—	28	15	650	260	1090	1060	
Mean			68	78	—2	8	2.1	2.2	3.8	1.7	27	15	650	520	1100	1070	
SEM			7	14	3	8	0.1	0.1	0.8	0.7	7	3	90	120	90	80	
P for the difference			<0.05		NS		NS		<0.05		NS		NS		NS		NS
Girls																	
9	13.1	—	64	61	—8	1	1.8	1.9	0.1	1.3	39	25	360	460	1450	1260	
10	12.2	BI	49	61	6	0	2.1	1.9	1.1	0.9	3	9	400	440	1000	1140	
11	12.2	—	72	64	5	—1	2.2	2.0	1.1	1.4	47	6.7	250	430	940	1020	
12	11.6	—	64	86	6	4	1.6	2.7	2.0	1.3	<1	<1	480	360	1270	990	
13	11.3	SC	60	63	—18	—15	2.0	2.6	3.1	1.3	1	23	220	300	1030	1020	
14	10.4	—	70	78	3	1	1.3	1.6	2.9	1.2	17	17	340	340	1130	980	
15	10.2	SC	51	55	0	—7	1.5	2.0	1.1	0.7	27	<1	410	300	1460	1300	
16	10.1	SC	45	53	10	—9	1.3	1.7	2.4	1.3	25	11	740	540	1240	1270	
Mean			59	65	0	—3	1.7	2.0	1.7	1.2	20	19	400	400	1190	1120	
SEM			4	4	9	2	0.1	0.1	0.4	0.1	6	8	60	30	70	50	
P for the difference			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
All children																	
Mean			64	71	—1	—6	1.9	2.1	2.6	1.4	23	17	530	460	1150	1090	
SEM			4	3	2	4	0.1	0.1	0.5	0.1	5	4	60	60	60	50	
P for the difference			<0.01		NS		NS		<0.02		NS		NS		NS		NS
P for the difference between boys and girls			NS	NS	NS	NS	<0.05	NS	<0.05	<0.01	NS	NS	<0.05	NS	NS	NS	NS

SC = Sodium chromoglycate, BI = inhaled beclomethasone, NS = not significant.
 Conversion: SI to traditional units—power: 1 W ≈ 6.12 kpm/min, lactate: 1 mmol/l ≈ 9 mg/100 ml, adrenaline: 1 nmol ≈ 0.18 μg, cortisol: 1 nmol/l ≈ 0.036 μg/100 ml.

Fig. 2 Exercise-induced mean levels of plasma cortisol and GH in 16 children with bronchial asthma; effect of 4 months' physical training on the response.

Bars indicate SEM.

Conversion: SI to traditional units—cortisol: 1 nmol/l $\approx$ 0.036 μ g/100 ml.

Discussion

Our 4-month biweekly training programme increased the physical working capacity and decreased submaximal exercise-induced responses in urinary adrenaline excretion and plasma cortisol levels in a group of asthmatic children. In contrast, GH response was not affected by the training.

As no healthy child was included, no direct comparisons can be made of the efficiency of our programme. However, the mean increase of 11% above the pretraining capacity for physical work is comparable with the increase of 15% in 6 healthy boys during a 6-month course of intensive training (Ekblom, 1969) and with the mean increase of 11% in 46 asthmatic children during a course of 5 months of swimming training (Fitch *et al.*, 1976). In most asthmatic children a 4- to 6-min period of hard exercise triggers an attack of bronchospasm (Jones *et al.*, 1962; Bierman *et al.*, 1975) with deleterious effect on the training intensity. Failure to compensate

for this effect may explain the failure of some intensive training programmes (Geubelle *et al.*, 1971; Vavra *et al.*, 1971). We avoided this effect by dividing the intensive training into short bursts of activity (Strick, 1969). In accord with Fitch *et al.* (1976), training did not affect the frequency of submaximal exercise-induced bronchospasm.

Exercise-induced increases in the secretion of adrenaline (Galbo *et al.*, 1975), cortisol (Few, 1974), and GH (Sutton and Lazarus, 1976) are directly proportional to the intensity of the work. Because the loads between the two tests were unchanged in our series, our findings could be explained by assuming that the ratio of work load to physical working capacity was decreased during the training period. Unchanged plasma lactate levels indicate that the decrease in this ratio was not crucial.

In trained healthy adults, submaximal exercise (Hartley *et al.*, 1972a) or prolonged exercise before exhaustion (Hartley *et al.*, 1972b) induced a lower response in plasma adrenaline level after a 7-week period of training. However, at maximal loads or after exhaustion the responses were unchanged. Plasma cortisol and GH levels indicated no consistent changes. Basal urinary adrenaline or urinary cortisol excretion showed no changes during a period of 6 weeks' training in healthy or obese adult men (Björntorp *et al.*, 1977). In untrained asthmatic children maximum exercise induced an increase in plasma adrenaline level similar to that seen in healthy children (Chrysanthopoulos *et al.*, 1978). Our results are inferred from short submaximal exercise tests and therefore cannot be generalised. Training could induce changes in exercise responses by modifying the rate of secretion, peripheral degradation or excretion of the hormones (Few, 1974), or the rate of blood flow in the adrenal glands.

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