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Humidity influences exercise capacity in subjects with Exercise-Induced Broncho - Constriction (EIB)

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■ **ABSTRACT**

The primary aim of the present study was to examine the effect of changing the humidity of the environmental air upon exercise capacity measured by peak oxygen uptake ($V^{\bullet}O_{2\ peak}$), peak ventilation ($V^{\bullet}E_{peak}$) and peak running speed ($V^{\bullet}_{peak}$) and secondarily to assess the influence of environmental humidity upon EIB in subjects suffering from EIB. Twenty subjects (10–45 years old, male/female:13/7) with diagnosed EIB performed exercise testing under standardised, regular environmental conditions, 20.2°C (±1.1) and 40 per cent (±3.3) relative humidity [mean (±sd)] and under standardised humid environmental conditions, 19.9°C (±1.0) and 95 per cent (±1.7) relative humidity in random order on separate days. Lung function was measured before and 1, 3, 6, 10 and 15min after exercise. Heart rate (HR), oxygen uptake ($V^{\bullet}O_2$), respiratory gas exchange ratio (RER), breathing frequency (BF) and minute ventilation ($V^{\bullet}E$) were measured during exercise. The results were indentified that $V^{\bullet}O_{2\ peak}$ and $V^{\bullet}_{peak}$ increased significantly from 40 per cent to 95 per cent relative humidity of the environmental air, 4.5 per cent and 5.9 per cent, respectively (P=0.001). HR_{peak} increased significantly in the humid environment, while BF_{peak} decreased significantly. The conclusion that exercises capacity ($V^{\bullet}O_{2\ peak}$ and $V^{\bullet}_{peak}$) markedly improved during exercise in humid air in subjects with EIB, whereas EIB was reduced to the half.

■ **KEY WORDS :** Peak oxygen uptake, Exercise capacity, Environmental humidity, Exercise-induced broncho-constriction

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Broncho-constriction is the constriction of the airways in the lungs due to the tightening of surrounding smooth muscle, with consequent coughing, wheezing and shortness of breath.

Exercise-induced broncho-constriction (EIB) is common in asthmatic children and adolescents and has been stated to occur in as much as 70–90 per cent of untreated asthmatics (Deal *et al.*, 1979). As EIB influences daily life activities and sports activities in children and adolescents, an accurate assessment of EIB is important to enable optimal choice of treatment. EIB is best assessed by a standardised exercise test, commonly used is running on a treadmill for 6–8min at a sub-maximal workload (Gilbert and McFadden, 1992 and Haby *et al.*, 1994). Lately it has been maintained that an exercise load corresponding to 95 per cent of estimated maximum heart rate (HR_{max}) (220 beatsmin^{-1} - age) is preferable to obtain a high sensitivity of the test.

EIB consists of broncho-constriction occurring immediately or soon after physical exercise and is mainly thought to be caused by the increased ventilation during exercise, such knowledge is needed for giving optimal advice and treatment to asthmatic children and adolescents competing in different sports, especially endurance sports and also as related to regular physical training of asthmatic children and adolescents (Carlsen *et al.*, 2000).

The Null hypothesis of the present study was that there is no difference in exercise capacity in subjects suffering from EIB exercising under regular, indoor conditions (20°C and 40% relative humidity) as compared to exercising under humid conditions (20°C and 95% relative humidity).

■ METHODOLOGY

Design :

The present study was randomised, cross-over with one test for exercise-induced broncho-constriction (EIB-test) in a standardised, regular indoor environment, 20.2°C (±1.1) and 40 per cent (±3.3) relative humidity [mean (±sd)] and another test in a standardised humid environment 19.9°C (±1.0) and 95 per cent (±1.7) relative humidity on two different test days. Intervals of at least 48h were required between each of the two tests. There were three study days in total. On day one, all subjects underwent an EIB-test to assess if they satisfied the inclusion criterion, a reduction in forced expiratory volume in 1s (FEV_1) 10 per cent from before to after exercise. If satisfying the inclusion criterion, the subjects were randomised consecutively to one of the two climate blocks according to random order generated by a computer programme. Eleven subjects were tested under regular indoor conditions first and nine subjects under humid conditions the first test day. The study could not be blinded because the subjects could immediately feel which climate they went into. The present study is part of a larger study also investigating the effect of changes in barometric pressure and temperature.

Subjects :

Twenty subjects, 10–45 years of age, were selected as a subjects the residents of Anantapuram town, Andhra Pradesh, with documented EIB (10% decrease in FEV_1 after a standardised EIB-test) were included into the study. The EIB-test on the screening day was performed under standardised, regular indoor conditions. Exclusion criteria consisted of any other diseases or use of any regular medication which might influence test results and any respiratory tract infection during the last 3 weeks before study inclusion. Another exclusion criterion was if the FEV_1 baseline measurement varied more than 5 per cent between the two test days.

Seventeen of the 20 subjects were atopic as defined by positive skin prick test (SPT). Seven subjects used regular inhaled steroids and 10 subjects used regular daily long-acting inhaled β_2-agonists. Seventeen subjects used short-acting β_2-agonists on demand, one subject used oral theophylline and two subjects used daily leukotriene antagonist. Four subjects used antihistamines, whereas nine subjects were without any regular asthma medication.

Five subjects participated in competitive sports, 14 participated in regular physical activity in school or leisure time and one subject rarely or never participated in physical activity.

EIB-test :

EIB was determined by running on a motor-driven treadmill ("Bodyguard" 2313, Sweden) for 8 min at a sub-maximal workload. The inclination of the treadmill was 5.3 per cent. The speed of the treadmill ($V^\bullet$) was adjusted during the first 4 min to achieve a workload corresponding to the maximum speed the subjects were able to keep the last 4min, at about 95 per cent of estimated maximum heart rate (220 beatsmin^{-1} - age).

Statistical analysis :

Demographics are given as mean values and standard deviation (SD) and results as means with 95 per cent confidence intervals (CI). Differences between the two tests were analysed by standard t-tests for paired samples when satisfying normal distribution. Correlation was calculated by Pearson's correlation co-efficient. Based upon $V^\bullet O_{2\ peak}$ and FEV_1 as main variables, with pre-existing knowledge of the variation of these variables and assuming a power of 80 per cent, a sample size of 20 subjects was calculated to obtain a significance level of 5 per cent.

■ OBSERVATIONS AND DISCUSSION

Demographic data and baseline lung function are given Table 1. Baseline lung function (FEV_1, FEF_{50} and

FVC) did not differ significantly on the two test days.

Exercise capacity, $V^{\bullet}O_{2\ peak}$ and $V^{\bullet}_{peak}$, increased significantly, 4.5 per cent and 5.9 per cent, respectively, during exercise in humid air. $V^{\bullet}O_{2\ peak}$ from 46.5mlkg^{-1}min^{-1} (43.9, 49.9) [mean (95% CI)] to 48.6mlkg^{-1}min^{-1} (45.5, 52.5), respectively, and $V^{\bullet}_{peak}$ from 10.2kmh^{-1} (9.3, 10.7) to 10.8kmh^{-1} (10.0, 11.3), respectively (P=0.001) (Table 2). HR_{peak} also significantly increased under humid conditions (P=0.003), while BF_{peak} significantly decreased (P<0.001) (Table 2). There were no significant differences in mean $V^{\bullet}E_{peak}$ and RER_{peak} during exercise between the two climatic conditions.

Values are given as mean and mean difference between the groups with 95 per cent confidence intervals in parentheses.

Calculated respiratory water loss during the last 3 min of exercise under regular indoor conditions was 10.4g (9.3, 11.5) vs. 7.8g (6.8, 8.8) in humid environment, respectively (P<0.001).

No significant correlation was found between reduction in lung function after exercise and water loss during the last 3min of exercise. Neither was there any significant correlation between maximum reductions in lung function after exercise (measured by FEV_1, FEF_{50}) or AUC or water loss during exercise and increased $V^{\bullet}O_{2\ peak}$ in the humid environment.

The present study demonstrated that exercise capacity measured by $V^{\bullet}O_{2\ peak}$, $V^{\bullet}_{peak}$ and HR_{peak} increased significantly during exercise under humid environmental conditions compared to regular indoor conditions. BF_{peak} was decreased in humid climate, whereas $V^{\bullet}E_{peak}$ and RER_{peak} did not differ.

The relatively large age range of the subjects in the present study reflects the period of life extending from school-age to adulthood, where human beings are physically active and spending time to physical activity.

The standardisation of the exercise load was based upon the screening test of the individual subjects aiming a submaximal to maximal exercise load as assessed by HR. The speed of the treadmill thus becomes a measure of performance during the two different climatic conditions.

In conclusion, exercising in a humid environment improves exercise capacity as measured by $V^{\bullet}O_{2\ peak}$

Table 1 : Demographic data and baseline lung function (% of predicted) before exercise in standard, regular environment, 20.2°C (±1.1) and 40 per cent (±3.3) relative humidity [mean (±sd)] and in a standard humid environment, 19.9°C (±1.0) and 95 per cent (±1.7) relative humidity of the 20 subjects included in the study

Variables	Mean±sd	(Range)
Age (years)	24±10.3	(10–45)
Gender ♀/♂	7/13	
Bodyweight (kg)	66.2±19.1	(34–111)
Height (cm)	171.1±11.0	(149–197)
Baseline FEV_1 (% predicted), 40% rel.hum.	100±13.6	(79–122)
Baseline FEV_1 (% predicted), 95% rel.hum.	100±15.7	(77–127)
Baseline FEF_{50} (% predicted), 40% rel.hum.	74±20.0	(45–111)
Baseline FEF_{50} (% predicted), 95% rel.hum.	77±22.4	(44–115)

Data are given as mean ± standard deviation with range in parentheses.

Table 2 : Peak oxygen uptake ($V^{\cdot}O_{2\ peak}$), peak heart rate (HR_{peak}), peak respiratory exchange ratio (RER_{peak}), peak breathing frequency (BF_{peak}), peak minute ventilation ($V^{\cdot}E_{peak}$) and peak running speed ($V^{\cdot}_{peak}$) during exercise test under standardised, regular conditions, 20.2°C (±1.1) and 40 per cent (±3.3) relative humidity [mean (±sd)] and under standardised humid conditions, 19.9°C (±1.0) and 95 per cent (±1.7) relative humidity (n=20)

Variables	40% relative humidity	95% relative humidity	Mean difference (95% CI)	Significance (P)
$V^{\cdot}O_2$ (mlkg^{-1}min^{-1})	46.5	48.6	–2.13 (–3.30, –0.96)	0.001
HR_{peak} (beatsmin^{-1})	186	189	–3.20 (–5.17, –1.23)	0.003
RER_{peak}	1.03	1.00	0.03 (–0.01, 0.07)	NS
BF_{peak}(breathmin^{-1})	46	43	2.22 (1.11, 3.33)	<0.001
$V^{\cdot}E_{peak}$ (Lmin^{-1})	99	100	–1.00 (–5.11, 3.11)	NS
$V_{t\ peak}$ (Lbreath^{-1})	2.24	2.34	–0.10 (–0.18, –0.031)	0.008
$V^{\cdot}_{peak}$ (kmh^{-1})	10.2	10.8	–0.66 (–1.01, –0.31)	0.001

NS=Non-significant

and $V^{\bullet}_{peak}$, and protects against EIB in subjects suffering from EIB. Similar work related to the present investigation was also carried our by Anderson *et al.*, 1971 and 1982; Eggleston and Guerrant, 1976 and Sterk *et al.*, 1993)

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