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Effect of a swimming training session on the exhaled breath temperature

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Professor Doutor André Moreira

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Effect of a swimming training session on the exhaled breath temperature

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Running title: Exhaled breath temperature in elite swimmers

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ABSTRACT

Background: By exercising, an inflammatory response of the airways occurs, with bronchial smooth muscle constriction and vasodilatation. The later could lead to an increase in exhaled breath temperature (EBT), possibly more pronounced in subjects with asthma. We aim to investigate the effect of a training session on EBT of elite swimmers and to assess if the impact is different in asthmatic vs non-asthmatic swimmers.

Methods: Swimmers that are annually screened for asthma in our Department were invited to this prospective study. The regular screening includes 2 visits in which subjects perform skin prick tests, spirometry before and after salbutamol inhalation and bronchial challenge with methacholine. Diagnosis of asthma was according to IOC-MC criteria. For those who agreed to participate, EBT was measured with X-halo thermometer before and after a training session. SPSS ($p<0.05$) was used to compare baseline and post-training EBT; and ΔEBT between asthmatic and non-asthmatic swimmers.

Results: 22 swimmers accepted to participate, of which 10 had asthma. EBT significantly increased after the training session ($p=0.020$). No significant differences were observed in mean ΔEBT among asthmatic and non-asthmatic swimmers ($p=0.222$).

Conclusions: EBT increased after a training session. There was no difference in EBT between asthmatics and non-asthmatics.

Key words: asthmatics, exhaled breath temperature, swimmers, training

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INTRODUCTION

Asthma is defined as a clinical syndrome of intermittent respiratory symptoms triggered by viral infections, environmental allergens, or other stimuli, and is characterized by nonspecific airway hyperesponsiveness and inflammation (1). Vasodilatation is a critical feature of inflammation, and angiogenesis and vascular remodeling are features of chronic inflammatory diseases, such as asthma (2). The increased vascularity of the airways in asthma is partly due to the elevated number of vessels associated with angiogenesis (3) and partly due to vasodilation caused by the release of vasodilator mediators, such as histamine, bradykinin and nitric oxide (NO).

As part of this inflammatory process, the increased vascularization of the airway mucosa that occurs in asthmatics, leads to increased heat exchange during expiration (4) and previous studies have reported that patients with asthma present an elevated exhaled breath temperature (EBT) compared to healthy controls (5). The elevation of exhaled NO as an inflammatory marker seen in asthmatics, has previously been shown to correlate with increased EBT (5, 6), and therefore EBT has been proposed as a non-invasive new biomarker for asthma control (7, 8).

Although the pathogenesis of the association of sports practice and airway injury is not fully elucidated, some hypotheses have been proposed, one of which focuses upon cooling of the airways caused by hyperpnea during exercise. Vigorous exercise requires an increased ventilatory rate to meet higher muscular oxygen needs, which results in the inhalation of a large volume of relatively cold and dry air and the loss of heat from the respiratory mucosa. This mechanic noxious stimulus could cause epithelial damage, and therefore the influx of inflammatory cells and their mediators release (9-11). Also, higher levels of airway vascular permeability have been shown to be a good predictor of the severity of EIA in asthmatics, which has led to the microvascular theory of EIA based on functional abnormalities of endothelial cells in newly generated microvessels in asthmatic airways (12).

It has been shown a significant increase in EBT in asthmatic children after exercise (13), but this increase is not different between asthmatics and controls (14). In athletes this was never investigated before and is a relevant issue as they present an increased risk for asthma, especially those who take part in endurance sports, such as swimming (10). We hypothesize that exercise would increase EBT, and a more pronounced increase in would be seen in asthmatic athletes as a greater degree of response to exercise as compared to healthy ones. Therefore, our aim was to investigate the effect

of a training session on EBT of elite swimmers, and to assess if the impact is different in asthmatic vs non-asthmatic swimmers.

METHODS

Study design and subjects

Elite swimmers of the FC Porto main swimming team who are annually screened for asthma and atopy at Allergy, Asthma and Sports Unit were invited to participate in this prospective study. The regular screening includes two visits, about 1 week apart, in which subjects are evaluated with skin prick tests, lung volumes before and after salbutamol inhalation, and airway responsiveness to methacholine. Swimmers are asked to withheld anti-asthmatic or anti-allergic medication that they might being possibly taking for both visits, according to European Respiratory Society guidelines (15). Inhaled short acting β2-agonists were withheld for 8 hours before testing; inhaled long-acting β2-agonists, theophylline, and leukotriene antagonists were withheld for the last 72 hours; antihistamines were withheld for the last 7 days; and both inhaled and orally administered corticosteroids were withheld for the last month. At that time, they are diagnosed as having or not asthma, according to International Olympic Committee criteria (16). Later, for those who agreed to participate in the study, EBT was collected before and after a training session at their swimming pool.

In order to be eligible to participate in this study, a subject had to meet all the following criteria: elite level swimmer; free from respiratory infection in the last 3 weeks; provided signed and dated informed consent. A potential subject who met any of the following criteria was excluded from participation in this study: pregnancy; recent episode of hemoptysis; forced expiratory volume in the first second (FEV_1) lower than 60% of the predicted value or 1.5 L; neurological or psychiatric illness; lack of collaboration or coexistence of diseases that limit the patient's ability to carry out the tests; recent stroke or heart attack.

All subjects gave written informed consent, and the study was approved by ethical commission of Centro Hospitalar São João / Faculdade de Medicina da Universidade do Porto.

Procedures

Methacholine challenge

Non-specific bronchial hyperesponsiveness was measured by methacholine challenge, according to guidelines (15). Methacholine was delivered by inspiration triggered by an automatic dosimeter that delivers a single dose soon after the onset of a deep breath. The five-breath dosimeter method was used and the provocative dose causing a 20% fall in FEV1 (PD_{20}) was determined.

Lung function

Spirometry was carried out according to the American Thoracic Society criteria (17). Lung function measurements were repeated 15 minutes after 400 µg of salbutamol in aerochamber to assess reversibility.

Skin prick tests

Skin prick tests were carried out in accordance international guidelines (18) with a standard battery of commercial extracts for common aeroallergens (Leti®, Madrid, Spain). Histamine dihydrochloride and diluent were used as positive and negative controls, respectively. Testing solutions were stored at +2 to +8ºC when not in use. The largest and perpendicular diameter of the wheal for each of the allergens is measured and the following value calculated: largest + perpendicular diameter/2. A subject is defined as atopic in the presence of at least one positive result (regarded if the value calculated was ≥3 mm and controls showed adequate reactions) (18).

Exhaled breath temperature

EBT was measure using an X-halo device (Delmedica Investments, Singapore), 5 minutes before (baseline EBT) and 5 minutes after (post-exercise EBT) the swimming training session, according to previously validated methods (20). Briefly, the swimmers were requested to inhale freely through the nose and to exhale into the device at a rate and depth typical of their normal tidal breathing rhythm. The maneuver was continued until the built-in software of the instrument indicated that the measured value was stable. The decision of collecting EBT 5 minutes after the exercise was based in previous studies that have shown that this was the time point in which EBT reached the highest values, and decreases thereafter (14).

The time needed to achieve the stable EBT was recorded. Before and between measures, the device was kept at room temperature in order to maintain a stable starting temperature.

The swimmers performed their regular training session and no changes were imposed by the investigators. The intensity of the training session was recorded (categorized as 1: mild aerobic training; 2: moderate/intense aerobic training; 3: mild anaerobic training; and 4: moderate/intense anaerobic training) in order to identify a possible confounding effect. The training was performed at a chorine disinfected open-air swimming-pool.

Body temperature

Oral temperature has been proposed to be related to the airways and/or the oral cavity, as both are part of the respiratory tract and are affected differently than systemic temperature during exercise (14), and therefore we have chosen axillary temperature to evaluate body temperature. It was measured with an axillary thermometer (MedCare®) before collecting baseline EBT.

Statistical analysis

Categorical variables are expressed as counts (%) and continuous variables as mean (standard deviation - SD) or, if not normally distributed, as median (interquartile range - IQR). Paired samples t-test was used to compare the differences between baseline and post-exercise EBTs. Differences between asthmatic and non-asthmatic swimmers were assessed with independent samples t-test for normally distributed data, Mann-Whitney for non-normally distributed data or Chi-Square for categorical variables. A new variable was created (ΔEBT = post exercise EBT – baseline EBT), and used to assess if the variation of EBT was different among asthmatic and non-asthmatic subjects. Correlations were assessed with Spearman's test.

All analyses were performed using SPSS and STATA and considering a $p<0.05$ for statistical significance.

RESULTS

Twenty-two elite swimmers accepted to participate, of which 10 had asthma. No differences were observed between asthmatic and non-asthmatic swimmers for demographic and personal characteristics, except for the expected lower PD_{20} among those with asthma (**table 1**).

Table 1:

Demographic and personal characteristics

	Asthmatics (n=10)	Controls (n=12)	p
Men, n (%)	7 (70)	3 (23)	0.084
Age	17 ± 2.8	17 ± 2.9	0.946
Atopy, n (%)	4 (40)	4 (33)	1.000
PD20 methacholine	0.71 ± 0.6	4.39 ± 2.4	**<0.001**
FEV_1, Liters	4.26 ± 0.75	4.07 ± 0.92	0.622
FEV_1, % of predicted	111.10 ± 14.54	115.50 ± 8.89	0.393
FVC, Liters	5.13 ± 0.94	4.60 ± 1.20	0.271
FVC, % of predicted	114.50 ± 10.49	114.08 ± 11.48	0.931
FEV_1/FVC	83.52 ± 7.32	89.36 ± 7.18	0.074
FEF_{25-75}, Liters	4.22 ± 1.20	4.67 ± 1.17	0.387
FEF_{25-75}, % of predicted	97.3 ± 26.67	113.42 ± 22.54	0.140

Data presented as mean±SD, unless otherwise stated.

FEF2575: forced expiratory flow middle portion of FVC; **FEV1**: forced expiratory volume in one second; **FVC**: forced vital capacity; **L**: liters; **PD20**: provocative dose inducing a 20% decrease in FEV1.

Exhaled breath temperature

Baseline and post-exercise EBT were not significantly different between asthmatic and healthy swimmers (**table 2**). EBT significantly increased after exercise in all subjects (p=0.020) (**figure 1**). This increase (∆EBT) was not significantly different among asthmatic swimmers and the healthy ones (p=0.222) (**figure 2**). Correlation between PD_{20} and ∆EBT for asthmatic swimmers was not significant (r=-0.103, p=0.777). Because 6 (60%) asthmatic swimmers were under therapeutic with inhaled corticosteroids at the time of EBT collection, a second analysis was performed and no differences were observed between those with and without therapy (p=0.853).

Correlations between axillary temperature and both baseline and post-exercise EBTs were not significant (p=0.972 and p=0.597, respectively).

Regarding time to collect EBT, no differences were observed from baseline to post-exercise measurements in the global sample (p=0.822). Also, for baseline EBT collection, no differences occurred between asthmatic and non-asthmatic swimmers (p=0.366). However, for EBT collection after exercise, asthmatic swimmers took significantly less time to complete the measurement (4.2±0.79 vs 5.0±0.85 min, p=0.035).

Training

No significant differences were observed between asthmatic and controls regarding the intensity of the training session performed (**table 2**). The number of hours trained in the week of EBT collection was similar in the two groups (**table 2**).

Table 2:

Temperatures measurements and training evaluation

	Asthmatic swimmers (n=10)	Healthy swimmers (n=12)	p
Baseline EBT, ºC	34.08 ± 0.60	33.49 ± 0.95	0.102
Post-exercise EBT, ºC	34.23 ± 0.55	33.94 ± 0.64	0.275
Body Temperature*	35.97 ± 0.42	36.02 ± 0.31	0.769
Hours of training in that week	9.4 ± 2.6	9.3 ± 3.4	0.910
Intensity of the session, *n*			0.121[#]
Mild aerobic	8	3	
Moderate/severe aerobic	1	0	
Mild anaerobic	1	5	
Moderate/severe anaerobic	2	2	

Data presented as mean±SD, except otherwise stated. *Axillary temperature was used as a measure for body temperature. [#]Chi-square test.

DISCUSSION

The hypothesis on the basis of this study was that elite swimmers would present increased EBT after a training session, due to the previously suggested idea that exercise would cause inflammation, and furthermore that asthmatic swimmers would experience a higher increase when compared to healthy controls. Interestingly, this could not be confirmed by this study. Although EBT was significantly increased in all subjects after training, supporting the hypothesis of heat loss during exercise, no differences were observed between swimmers with previously diagnosed asthma and healthy controls. It is therefore tempting to speculate that the theory of the heat loss as an ethiopathogenic mechanism of exercise-induced asthma lacks evidence.

Our study has some limitations. The sample size might under power the study to draw solid conclusions. Moreover, a cause that may have affected the results could be the 20 minutes of recovery (swimming with low effort) that swimmers made in the end of the training session and that decreases cardiac rhythm, respiratory frequency and the hyperpnea that makes EBT increase. If the temperature has been taken in the end of a more vigorous exercise instead at the end of the training this could lead to a marked results in ΔEBT.

Our results are consistent with previous studies that also have show an increase in EBT after exercise (13), but no differences between asthmatic subjects and healthy controls (14). That was different of other studies that shown differences in EBT of asthmatic patients compared to healthy controls (5). This raises the question whether the EBT could be a good inflammatory biomarker of asthmatics.

Previously has been hypothesized that dehydration of the airways with increased osmolality in the mucosal surface liquid leads to mast cell degranulation (21, 22), releasing bronchoconstriction mediators, such as bradykinin and histamine, and activating endothelial nitric oxide synthase (23), witch increase the vasodilation effect. This could suggest that elevated EBT could be a potential marker of a temporary effect on the airways, rather than of the long-term inflammation of the asthmatic disease. So the increase of EBT could be a physiological response of the airways to the increase of ventilatory rate, rather than a pathological pathway which can be involved in development of exercise-induced asthma.

This study leads us to hypotheses that the increase of EBT and there for the elevation of airway inflammation shown in previous studies (5, 6), during exercise (13), could be

a protect measure of the airways against heat loss and dehydration, that occurs with the increase of ventilatory rate, rather than a pathological result.

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ANEXO

1 - Normas da revista: Pediatric Allergy and Immunology

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