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ORIGINAL

EXERCISE-INDUCED BRONCHOCONSTRICTION WITHOUT FLUID REPLACEMENT

BRONCOCONSTRICCIÓN INDUCIDA POR EJERCICIO SIN REPOSICION HIDROELECTROLÍTICA

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ABSTRACT

Dehydration of the respiratory epithelium has been identified as a possible cause of exercise-induced bronchoconstriction (EIB). The aim of study was determine the effects of body dehydration on EIB. We measured FEV_1, FEV_1/FVC and FEF_{25-75} in 19 university soccer players (age: 20.5 ± 2 years) at 5, 10 and 15 minutes after exercise in hyperthermic conditions, with and without hydration. A 47.3% of the dehydrated group developed bronchoconstriction at 5 minutes post-exercise, 42.1% continued with this condition at 10 minutes and 26.3% kept it after 15 minutes post-exercise. None of the subjects rehydrated developed EIB. Results allow us to infer that some athletes are at risk for reduced lung function by more than 2% of body weight.

KEY WORDS: Bronchospasm, hydration, spirometry.

RESUMEN

La deshidratación del epitelio respiratorio ha sido identificada como una posible causa de la broncoconstricción inducida por ejercicio (BIE). El objetivo del estudio fue determinar los efectos de la deshidratación corporal en la BIE. Se midió el VEF_1, VEF_1/CVF y FEF_{25-75} en 19 futbolistas universitarios (edad: 20.5 ± 2 años) al minuto 5, 10 y 15 tras la realización de ejercicio en ambiente caluroso, con y sin hidratación. En el grupo deshidratado el 47.3% desarrolló broncoconstricción a los 5 minutos de finalizado el ejercicio, un 42.1% continuó con esta condición a los 10 minutos y un 26.3% la mantuvo luego de 15 minutos de finalizado el ejercicio. Ningún sujeto euhidratado desarrolló BIE. Los resultados observados nos permiten inferir que algunos deportistas son susceptibles de desarrollar una menor función pulmonar posterior a una deshidratación mayor al 2% del peso corporal.

PALABRAS CLAVE: Broncoespasmo, hidratación, espirometría.

INTRODUCTION

The occurrence of bronchoconstriction is common in asthmatics who exercise. In fact, most, if not all patients will have symptoms such as cough, wheezing and dyspnea, a situation known as exercise-induced asthma (1). Nevertheless, it is possible that subjects with no history of asthma or atopy experience bronchial obstruction caused by physical activity (2). This reduced diameter of the airway is called exercise-induced bronchoconstriction (EIB) (3).

Some research groups have found that the prevalence of EIB is between 11 and 50% in elite athletes (4-7). These values are similar to those found in healthy non-athlete subjects. In this context, the Rupp group noted that 28.6% (n=230) of non-asthmatic schoolchildren, but with risk factors, experienced EIB (8). Aissa et al. evaluated 196 teenage soccer players with no clinical history of asthma, of whom a 30% developed bronchoconstriction after a vigorous exercise test (9). Thus, we can see that EIB frequently occurs in apparently healthy subjects without a history of asthma, so it is imperative to have new diagnostic strategies for its detection.

The most accepted hypothesis for the emergence of EIB is related to an increase in the ventilation flow rate and inspired-air cooling during vigorous exercise, which would cause the dryness of the distal airway epithelium by changing its osmolarity (10). This osmolar increase of the epithelium would cause the release of inflammatory mediators developing bronchoconstriction (11,12).

However, it is known that systemic dehydration greater than 2% of body weight (2BW) significantly modifies cell volume and the ionic balance of sodium and chloride (13). Epithelial water control directly depends on these factors, so, a deep dehydration during a long-lasting and moderate intensity exercise under

hyperthermic conditions, could favor the development of bronchoconstriction by changing the osmolarity of the respiratory epithelium.

Currently, there is no scientific evidence linking the effects of systemic dehydration induced by moderate exercise, under hyperthermic conditions, on the pulmonary function. Therefore, the objective of this research is to evaluate the acute bronchoconstrictor response in college athletes, after an exercise testing in steady state conditions with dehydration greater than or equal to 2% of body weight.

MATERIALS AND METHODS

Participants

A purposive sample of 19 male athletes of the Universidad Santo Tomás of Viña del Mar, Chile, was assessed. Average age, height and weight were 20 ± 2 years, 177.8 ± 7.1 cm and 73 ± 7.5 kg, respectively.

The fact that college students undertook sports training (physical activity) at least three times a week, that they had health compatible with the stress test and a standard spirometric evaluation prior to the visit to the laboratory were established as inclusion criteria. On the other hand, subjects who, during the last three weeks, had acute conditions that could alter the accuracy of the results or affect their physical integrity were excluded. Also, subjects with medical history suggestive of asthma and/or atopy were discarded.

The study was approved by the ethics committee of the Faculty of Health at the Universidad Santo Tomas. Athletes were previously informed and instructed about the procedure and they indicated their willingness to participate by signing a written informed consent according to the Helsinki declaration.

Procedures

Exercise Protocol

Subjects exercised under hyperthermic conditions and relative humidity (T °: 30°C and RH: 60%) under hydrated (H) and non-hydrated (NH) conditions with a difference of one week between assessments. Subjects under NH condition were evaluated first; the protocol consisted of performing prolonged steady-state exercise on a treadmill (SportArt-T610, USA). The programmed speed allowed each subject to maintain intensity at 60% of heart rate reserve (14). After 45 minutes of exercise, the level of dehydration was assessed by observing the variation in body weight.

In the evaluation under H conditions, participants had to exercise at a time individually obtained under previous NH conditions; during that period they were given 300 ml of isotonic drink every 15 minutes at a temperature of 15-21°C (15).

Dehydration

The level of dehydration was observed by measuring the body weight at the beginning and end of exercise (Detecto-439 scale, USA). All participants reached the 2BW by sweating during 45 ± 2 minutes of exercise. Once the test was finished, the spirometric evaluation was initiated (see Spirometry section).

Spirometry

Spirometry was performed 5 minutes prior to exercise (basal values) and at 5, 10 and 15 minutes post-exercise, according to the procedures described by Gutiérrez et al.(16). All measurements were performed under resting conditions, as recommended by the American Thoracic Society (17).

Comparative analyses in the study were conducted on the forced expiratory volume in the first second (FEV_1), forced vital capacity (FVC) and mid-expiratory flow (FEF_{25-75}), obtained with a Pony FX spirometer (Cosmed®, Pony FX, Italy).

Heart Rate

The heart rate (HR) was measured using a Polar RS800CX heart rate monitor (Polar, Finland). Monitoring of exercise intensity at 60% of heart rate reserve was maintained throughout the exercise protocol.

STATISTICAL ANALYSIS

In order to observe the effects of dehydration on the acute bronchoconstrictor response, mean basal values of FEV_1, FEV_1/FVC and FEF_{25-75} with those obtained at 5, 10 and 15 minutes post-exercise were compared. The statistical test used was the U Mann-Whitney test for paired data. Also, percentages of mean and individual changes with respect to their baselines were presented, considering a higher drop at 10% in FEV_1 and 30% in FEF_{25-75} as an indicator of bronchial obstruction. In addition, a lower limit of normal (LLN) for the FEV_1/FVC ratio of each subject where any value lower than this one determined the development of bronchoconstriction was defined (16). A statistically significant result was considered when the size of type I error was <0.05.

RESULTS

Age, physical characteristics and baseline spirometry variables of participants are shown in table 1. Values show the homogeneity of the population.

Table 1. Means ± standard deviation of age, physical characteristics and baseline spirometry variables of participants

Variables	Pre-exercise	Post-exercise	
		Hydrated subjects	***Non- hydrated subjects***
Age (years)	20.5 ± 2.0		
Height (cm)	177.8 ± 7.1		
Weight (kg)	73.0 ± 7.5	73.7 ± 5.4	71.4 ± 5.5
BMI (kg/m^2)	23.1 ± 2.2		
Basal FEV_1(L)		4.62 ± 0.45	4.63 ± 0.45
Basal FEV_1/FVC		0.84 ± 0.05	0.85 ± 0.05
Basal FEF_{25-75} (L/s)		5.34 ± 0.32	5.32 ± 0.38

BMI: Body mass index, FEV_1: Forced expiratory volume in the first second, FEV_1/FVC: Forced vital capacity and FEF_{25-75}: Mid-expiratory flow between 25% and 75% in FVC.

FEV_1

As shown in Table 2, only in the NH group, significant drops were observed in FEV_1 post-exercise means in relation to the baseline mean ($p<0.05$).

These drops did not exceed the rate of bronchial obstruction, meaning that they were not higher than 10% of the basal value. However, 47.3% (n = 9) of the individual values in the NH group had a drop in FEV_1 higher than 10% at 5 minutes post-exercise. From this group, 88.8% (n = 8) continued with bronchoconstriction within 10 minutes, and from this latter group 62% (n = 5) still had it after 15 minutes post-exercise (Figure 1). When participants exercised under hydration conditions, FEV_1 levels did not show any difference (Figure 1).

FEF_{25-75}

Subjects from the NH group showed significant differences ($p<0.05$) and drops higher than 30% in all FEF_{25-75} post-exercise means in relation to the basal value (Table 2).

By analyzing individual differences in FEF_{25-75},it was observed that 47.3% (n=9) of subjects belonging to the NH group maintained drops higher than 30% in relation to the basal values at 5, 10 and 15 minutes post-exercise (figure 1). When participants exercised under hydration conditions, FEF_{25-75} levels did not show any difference (figure 1).

Table 2. Means ± standard deviation of $FEV_{1,}$ FEV_1/FVC and FEF_{25-75} measured in both groups before and after exercise, with and without hydration.

Spirometric Variables	Groups	Pre-exercise	Post-exercise		
		Basal values	*5 min*	*10 min*	*15 min*
FEV_1 (L)	H	4.62 ± 0.43	4.53 ± 0.47	4.62 ± 0.42	4.63 ± 0.41
	NH	4.63 ± 0.45	4.24 ± 0.5 [a]	4.28 ± 0.47[a]	4.35 ± 0.47[a]
FEV_1/FVC	H	0.85 ± 0.05	0.85 ± 0.05	0.85 ± 0.05	0.85 ± 0.05
	NH	0.84 ± 0.05	0.78 ± 0.07[a]	0.78 ± 0.06[a]	0.8 ± 0.06[a]
FEF_{25-75} (L/s)	H	5.34 ± 0.32	5.28 ± 0.9	5.31 ± 0.8	5.31 ± 0.8
	NH	5.32 ± 0.4	3.45 ± 1.2[a,b]	3.63 ± 0.9[a,b]	3.7 ± 0.8[a,b]

FEV_1: Forced expiratory volume in the first second, FEV_1/FVC: Ratio between forced expiratory volume in the first second and forced vital capacity (Tiffenau Index) and FEF_{25-75}: Forced expiratory flow at 25% and 75% of FVC. H: Hydrated group and NH: Non-hydrated group. a: p<0.05 in relation to the basal value; b: mean drop higher than 10% in FEV_1 and 30% in FEF_{25-75}

FEV_1/FVC

The NH group showed significant differences in all post-exercise FEV_1/FVC means in relation to the basal value (table 2, p<0.05).

By analyzing the individual differences of FEV_1/FVC, it was observed that after 5 minutes post-exercise, 31.5% (n = 6) of dehydrated participants obtained values below their LLN (Figure 2). From these participants, 83.3% (n = 5) continued with this condition for 10 minutes and from the latter 80% (n = 4) maintained reduced LLN after 15 minutes post-exercise. In this context, none of the subjects in the H group obtained values below their LLN (Figure 2).

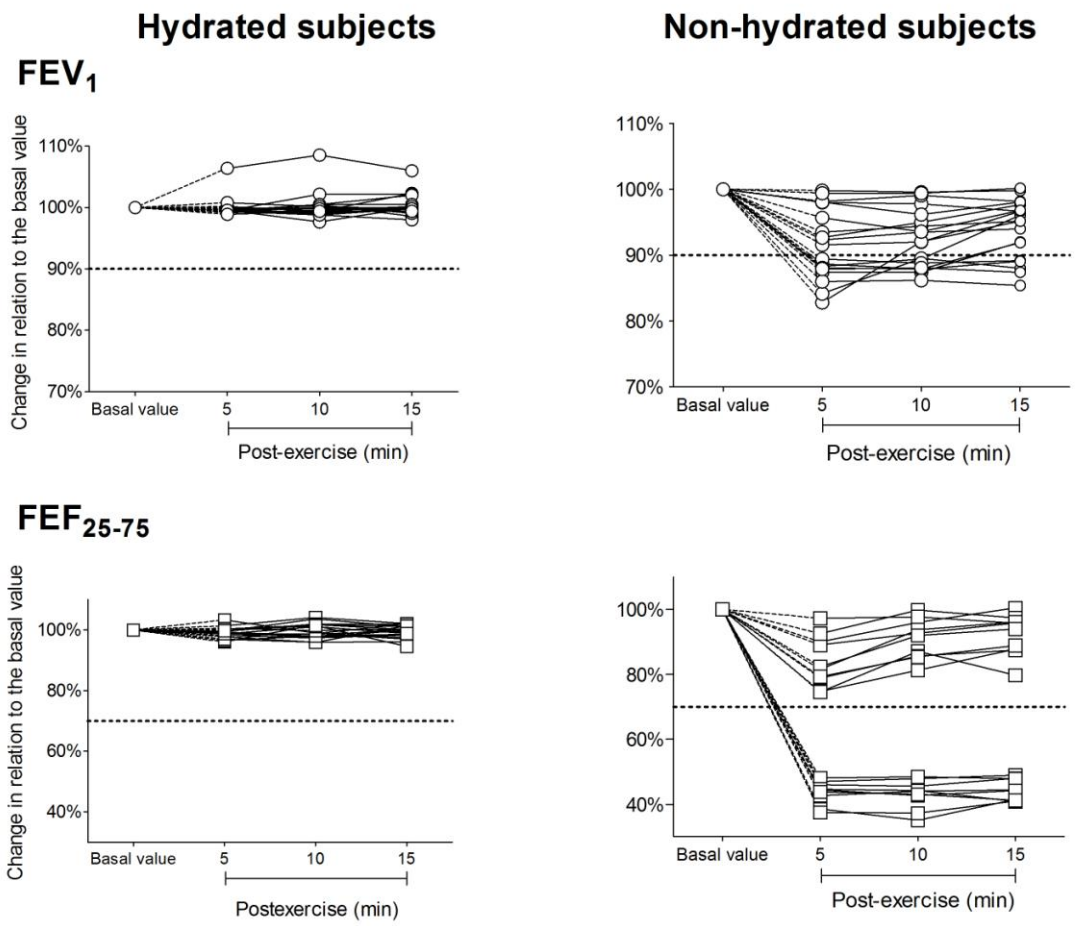

Figure 1. Baseline and post-exercise individual percentages in FEV_1 and FEF_{25-75} for both groups. The dotted line shows the drop percentage limit for FEV_1 higher than 10% (y=90%) and 30% for FEF_{25-75} (y=70%). FEV_1: forced expiratory volume in the first second and FEF_{25-75}: forced expiratory flow between 25% and 75% of forced vital capacity.

DISCUSSION

The results of this study allow us to infer that some athletes are susceptible to developing bronchoconstriction caused by exercise-induced dehydration. Indeed, the individual drops in this study were higher than 10% in FEV_1, 30% in FEF_{25-75} and LLN in FEV_1/FVC, only in the NH group.

An important aspect of our findings was that during correlated spirometric evaluations after exercise, no new cases of bronchoconstriction occurred. Also, it should be noted that the sample was divided into 2 groups, which were composed of the same subjects in 2 different intervention conditions (with and without fluid replacement). This means that the results reflect an inferential tendency on the effects of dehydration in the EIB.

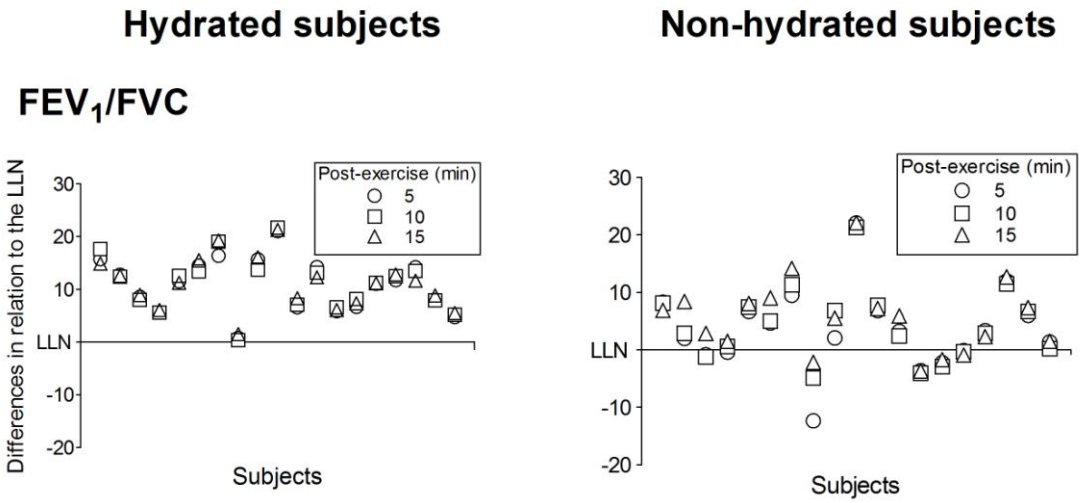

Figure 2. Individual variations in FEV_1/FVC in relation to the lower limit of normal for each subject under hydration and non-hydration conditions. FEV_1/FVC: ratio between forced expired volume in the first second and forced vital capacity.

Research groups have strengthened the hypothesis that the EIB is triggered by osmolar changes in epithelial cells. These changes would occur due to high airflow slightly dampened when the subject performs vigorous exercise in a cold, low humidity environment (18,19). These osmolar changes of entire epithelium favor cell deterioration, allowing the output of vascular elements from the subepithelial plexus. This will initiate an exudative response that involves participation of inflammatory cells such as eosinophils, basophils and mast cells (12,20). The intensities of exercise required to trigger this effect are greater than 80% of the maximum capacity of effort (2,3,18,21,22).

Notwithstanding the aforementioned, we believe that epithelial osmolarity may be affected by a deep systemic dehydration caused by long-term exercise under hyperthermic conditions.

One possible hypothesis is related to the high levels of dehydration and loss of sodium and chlorine electrolytes by perspiration after exercising under these conditions. It is worth recalling that a dehydration greater than or equal to 2PC causes significant decreases in intracellular water volume by altering osmolarity (13). Likewise, sodium and chlorine are essential elements in the water exchange process between the interior and exterior of the respiratory epithelium (23).

In order to corroborate the previously mentioned hypothesis, the one described by Chen et al. (2000) shall be recalled. This group suggested that the net flow of water through the apical and basolateral membrane of epithelial cells in the respiratory tract (J_W^{NET}) is determined by the sum of two factors: the water flow associated with an osmotic gradient (J_W^{Osm}) plus the water flow associated with the transmembrane ion movement (J_W^{Ion}). This is $J_W^{NET} = J_W^{Osm} + J_W^{Ion}$ (24). In this way, cell epithelial water loss by deep dehydration, as well as the loss of sodium and chloride by diffuse transpiration shall compromise the osmotic

gradient and transmembrane ion movement altering the net flow of water into the epithelium.

According to the above, the development of EIB in susceptible subjects shall depend on the athlete's ability to maintain hydration of the airway during exercise under hyperthermic conditions. Similarly, and according to our results, we can confirm that adequate hydration will be able to allow these individuals with adequate pulmonary function to finish the competition.

Moreover, the location where the physical activity is performed will be important to athletes. In this sense, the Rundell group (2008) observed significant differences in lung function between provocation tests performed in the laboratory and in the field, in either outdoor or indoor sports locations (25). It is possible that the subjects evaluated in our study may present lower spirometric values after exercise-induced dehydration in hot outdoor environments, determining an increased sensitivity to develop bronchial obstruction on the field. Similarly, Haathela et al. (2008) hypothesized that inhaled particles in the sports field can trigger increased bronchoconstrictor response in athletes (26). An example of this is swimmers, who constantly inhale disinfectant substances present in water, such as chlorine derivatives.

Another aspect to be considered is athletes who do not perform adequate hydration protocols during a long-term competition (27), for example, a marathon. This could also happen in a sport which does not allow fluid replacement during its development, as in soccer. In addition to all the previously mentioned factors, if increments in the intensity of effort during a competition are added, it is possible that these conditions may trigger higher levels of bronchoconstriction in athletes, causing a significant decrease in their performance.

CONCLUSIONS

Our results enable us to conclude that lung function may be affected by significant changes in systemic hydration after moderate intensity exercise under hyperthermic conditions. Therefore, proper hydration would avoid the development of bronchoconstriction in susceptible athletes by improving their performance.

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