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Short communication

Feasibility to apply eucapnic voluntary hyperventilation in young elite athletes

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ABSTRACT

Introduction: Exercise-induced bronchoconstriction (EIB) is more common in athletes compared to the general population. The eucapnic voluntary hyperventilation test is used to detect EIB in adult athletes. It is however unclear whether this technique is also applicable to young athletes.

Methods

Young athletes (basketball (n = 13), football (n = 19), swimming (n = 12)) were recruited at the start of their elite sports career (12–14 years). Eight age-matched controls were also recruited. Eucapnic voluntary hyperventilation test was performed according to ATS guidelines in all subjects. A second (after 1 year, n = 32) and third (after 2 years, n = 39) measurement was performed in a subgroup of athletes and controls.

Results

At time of first evaluation, 3/13 basketball players, 4/19 football players, 5/11 swimmers and 1/8 controls met criteria for EIB (fall in $FEV_1 \geq 10\%$ after EVH). A ventilation rate of >85% of the maximal voluntary ventilation (MVV) is recommended by current guidelines (for adults) but was only achieved by a low number of individuals (first occasion: 27%, third occasion: 45%) However, MVV in young athletes corresponds to 30 times FEV_1, which is equivalent to 85% of MVV in adults. A threshold of 70% of MVV (21 times FEV_1) is feasible in the majority of young athletes.

Conclusion

EIB is present in a substantial number of individuals at the age of 12–14 years, especially in swimmers. This underscores the importance of screening for EIB at this age. EVH is feasible in young elite athletes, however target ventilation needs to be adjusted accordingly.

A high prevalence of exercise-induced bronchoconstriction (EIB) has been reported among elite athletes [1]. Especially endurance athletes and athletes exposed to cold air (cross-county skiers) or chlorine derivatives (swimmers) are at risk [2–4]. A decrease in FEV_1 of 10% or more after eucapnic voluntary hyperventilation (EVH) has been proposed by the International Olympic Committee as diagnostic criterium for EIB in adult athletes. We studied whether the EVH test is also applicable for use in adolescent athletes (12–14 years).

Nineteen football players (12.9 ± 0.67 years) and 13 basketball players (12.4 ± 0.49 years) were randomly recruited from the Belgian elite sport high school and 12 swimmers (12.9 ± 0.76 years) were recruited from the Flemish future team. Eight age-matched controls, performing sports at a recreational level (≤6 h/week), were recruited from regular high schools. All individuals were analyzed outside the pollen season. Some individuals also performed a second (after 1 year) and third (after 2 years) EVH test. Written informed consent was obtained from all participants. The

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study was approved by the institutional review board and registered at clinicaltrials.gov (NCT02432183). Three swimmers and one basketball player had physician-diagnosed asthma and were treated with short-acting β_2-agonists and inhaled corticosteroids (ICS) (Table 1). Participants on ICS were asked to stop their medication 48 h before the EVH test. Short-acting β_2-agonists were allowed until 8 h before the test. Twelve athletes complained of intermittent exercise-induced respiratory symptoms such as dyspnea, wheezing and coughing. The EVH test was performed according to the ATS guidelines which has been described for adults [3,5]. In brief, EVH was performed for 6 min at a target ventilation of 85% of the maximal voluntary ventilation (MVV), which was determined before initiation of the test. Ventilation was monitored during the 6-min test by a flow sensor (Jaeger Oxycon Mobile, Carefusion), FEV_1 was measured immediately after challenge and at 5, 10 and 15 min. A reduction in $FEV_1 \geq 10\%$ at one of the time points compared with the value before the test was considered positive. Salbutamol (400 μg) was given after the last spirometry (post-EVH) to check bronchodilator reversibility. Lung function was assessed 15 min later and an increase in FEV_1 >250 ml or 12% was considered positive.

EVH induced a drop of at least 10% in FEV_1 in 13% of control subjects (1/8), 23% of basketball players (3/13), 21% of football players (4/19) and 58% of swimmers (7/12). In all but 4 subjects a drop in $FEV_1 \geq 10\%$ was observed at 2 or more time points, which recently has been suggested for diagnosis of EIB [6]. To rule out muscle fatigue as a cause of a single drop in FEV_1 we have analyzed the bronchodilator response after EVH. Significant improvement was present in three subjects (300 ml and 13%; 540 ml, 17%; 300 ml, 9%) suggestive for a bronchoconstriction response during EVH.

Three of the four subjects with physician-diagnosed asthma who were treated with ICS or short-acting β_2-agonists had a negative EVH test (i.e. max fall in FEV_1: −17.98%, −6.53%, −4.70% and −1.24%). This low response to EVH could be due to chronic treatment with inhaled corticosteroids, despite ICS withdrawal 48 h before the test.

In response to EVH we observed a simultaneous fall in FVC of >10% in 1 swimmer (at first time) and 2 controls (at second time) and were excluded from analysis. A fall in FEV_1 of 10% or more is only interpretable when FVC remains unchanged compared with baseline [7].

Thereby, twenty-three percent of basketball players (3/13), 21% of football players (4/19), 54% of swimmers (6/11) had a positive EVH test at enrollment to an elite sport program compared to 13% of control subjects (1/8) (Fig. 1A). The proportion of individuals with a positive EVH test was significantly higher in the swimmers compared to the controls ($Chi^2 = 3.5$, $p = 0.03$). Eleven athletes (26%) did not have physician-diagnosed asthma but did have a positive EVH test. Only four of the twelve athletes with a positive EVH test reported exercise-induced respiratory symptoms (wheezing, coughing and/or dyspnea), suggesting that EIB cannot be diagnosed based on reported symptoms only.

It is noteworthy that several children were unable to maintain a ventilatory target of 85% of the MVV until the end of the test. Only 27% of the subjects had an average ventilation rate of >85% of MVV when they performed the test for the first time, 21% at the second time compared to 45% at the third time they performed the test (Fig. 1B). To determine the maximal achievable ventilation in relation to FEV_1 we have calculated the $MVV_{(measured)}/FEV_{1(measured)}$ ratio for each individual. On average this ratio was 29 for basketball players, 31 for football players and 31 for swimmers. A comparison between adults and our findings in young athletes is given in Table 2. We suggest a threshold of 70% of MVV in young athletes because this corresponds to 21 x FEV_1 in those athletes, which is generally accepted as the lower limit for EVH in adults. Several studies reported a minimum threshold of 60% MVV for an adequate challenge in non-trained individuals [8–10]. This threshold was reached in 89% of subjects at the first time, 97% at the second time and 100% at the third time (Fig. 1B). A learning curve for the MVV was observed after 2 and 3 years but this effect might also caused by increased respiratory performance due to body growth, hormonal changes and the fact that they are more trained athletes over time. For this study, we did not exclude subjects based on the achieved MVV. Nevertheless, this may have led to false negative results in this specific population.

Besides the EVH test, several other exercise and surrogate tests can be used to diagnose EIB in adult athletes [11,12]. However, little is known about diagnosing EIB in a pediatric population. Sánchez-García and co-workers recently reported that the combination of the methacholine challenge test followed by a mannitol test is the best approach to diagnose bronchial hyper responsiveness in children [13]. Nevertheless, the EVH test was not included in their analysis. Further studies, in larger populations, are also required to investigate the sensitivity of the (optimized) EVH test in adolescents.

In conclusion, EIB is detected in a substantial number of young athletes at time of enrollment to an elite sport program, especially in swimmers. Therefore, it is advised to perform an EVH test in athletes training at elite sports level. A ventilatory target of 70% corresponds to 21 x FEV_1 in young athletes and is feasible for the majority of athletes. However, other studies have to confirm specificity and sensitivity of the test using this cut-off value. The bronchodilator reponse after EVH might help to rule out muscle fatigue if a drop in FEV_1 is observed at only 1 time point.

Table 1
Subject characteristics.

	Basketball players	Football players	Swimmers	Controls	P value[b]
Number (n)	13	19	12	8	
Age (years)	12.4 ± 0.49	12.88 ± 0.67	12.92 ± 0.76	13.79 ± 0.89	
Gender (M/F)	7/6	15/4	10/2	2/6	
Atopy[a]	5	6	3	1	
Seasonal	3	3	0	1	
Perennial	4	5	3	1	
Short-acting β_2 agonists	1	0	3	0	
Inhaled corticosteroids	1	0	3	0	
FEV_1 (L)	3.17 ± 0.57	3.23 ± 0.54	3.26 ± 0.42	2.85 ± 0.70	0.4823
FEV_1%predicted	101.68 ± 12.93	114.35 ± 15.84	105.81 ± 8.79	96.94 ± 18.02	0.1827
FVC (L)	3.79 ± 0.76	3.70 ± 0.65	4.15 ± 0.58	3.38 ± 1.00	0.0990
FVC %predicted	102.37 ± 16.78	110.84 ± 16.29	110.92 ± 11.49	99.76 ± 23.03	0.1860

[a] A subject is considered to be atopic if at least one allergen was positive during the skin prick test (wheal > 3 mm).
[b] One-way analysis of variance.

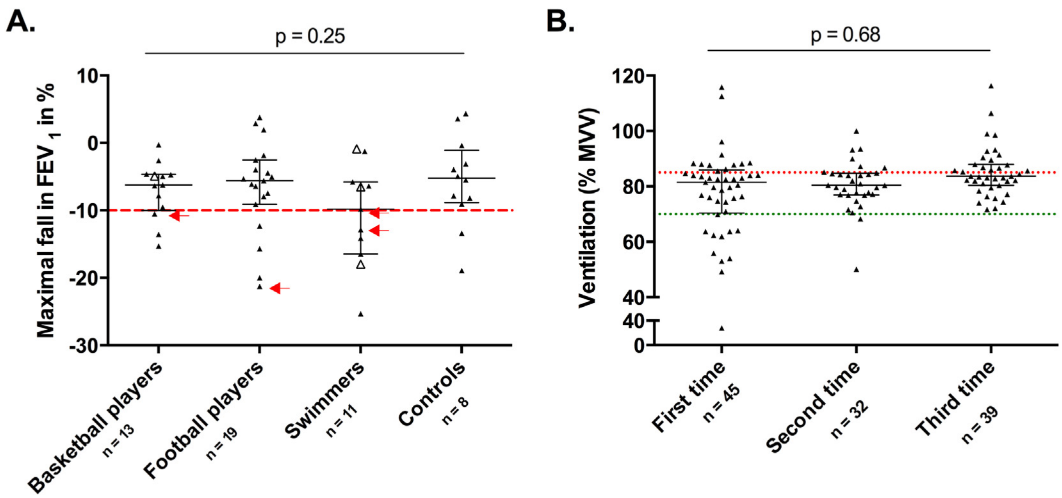

Fig. 1. Eucapnic voluntary hyperventilation test in athletes and controls. A: Maximal fall in FEV_1 (% of baseline) Data is presented as mean with standard deviation. One-way analysis of variance with Bonferroni post test was used to compare all groups. Subjects treated with ICS and β_2 agonist are represented with open symbols. Subjects in which the drop in FEV_1 was found at only 1 occasion were marked by an arrow. B: Average ventilation during EVH test (% of maximal voluntary ventilation (MVV)). Data is presented as median with interquartile range. The test was repeated three times with 12-month intervals.

Table 2
Comparison of maximal ventilatory capacity between adults and adolescents.

% Of MVV	Adults	Adolescents (12-14 y)
100%	$35 \times FEV_1$	$30 \times FEV_1$
85%	$30 \times FEV_1$	
70%		$21 \times FEV_1$
60%	$21 \times FEV_1$	

A ratio of the measured MVV and measured FEV_1 was made and calculated for each athlete. On average young athletes, referred as adolescents, had a ratio of 30. Thus, 100% of MVV in adolescents is 30 x FEV_1. On the other hand, 35 x FEV_1 is accepted as an equivalent of 100% of MVV in adults.

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