Exercise-induced bronchoconstriction in elite long-distance runners in Brazil*,**

Broncoespasmo induzido por exercício em corredores brasileiros de longa distância de elite

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Abstract

Objective: To determine the prevalence of exercise-induced bronchoconstriction among elite long-distance runners in Brazil and whether there is a difference in the training loads among athletes with and without exercise-induced bronchoconstriction. **Methods:** This was a cross-sectional study involving elite long-distance runners with neither current asthma symptoms nor a diagnosis of exercise-induced bronchoconstriction. All of the participants underwent eucapnic voluntary hyperpnea challenge and maximal cardiopulmonary exercise tests, as well as completing questionnaires regarding asthma symptoms and physical activity, in order to monitor their weekly training load. **Results:** Among the 86 male athletes recruited, participation in the study was agreed to by 20, of whom 5 (25%) were subsequently diagnosed with exercise-induced bronchoconstriction. There were no differences between the athletes with and without exercise-induced bronchoconstriction regarding anthropometric characteristics, peak oxygen consumption, baseline pulmonary function values, or reported asthma symptoms. The weekly training load was significantly lower among those with exercise-induced bronchoconstriction than among those without. **Conclusions:** In this sample of long-distance runners in Brazil, the prevalence of exercise-induced bronchoconstriction was high.

Keywords: Athletes; Asthma, exercise-induced; Exercise test.

Resumo

Objetivo: Determinar a prevalência de broncoespasmo induzido por exercício em corredores brasileiros de longa distância de elite e se há uma diferença na carga de treinamento entre atletas com e sem broncoespasmo induzido por exercício. **Métodos:** Estudo transversal com corredores de longa distância de elite sem sintomas atuais de asma e sem diagnóstico de broncoespasmo induzido por exercício. Todos os participantes foram submetidos ao teste de hiperventilação voluntária eucápnica e ao teste cardiopulmonar de esforço máximo e responderam a questionários sobre sintomas de asma e atividade física para monitorizar sua carga de treinamento semanal. **Resultados:** Dos 86 atletas do sexo masculino recrutados, 20 concordaram em participar do estudo, dos quais 5 (25%) foram diagnosticados com broncoespasmo induzido por exercício. Não foram evidenciadas diferenças entre os atletas com e sem broncoespasmo induzido por exercício em relação a características antropométricas, consumo de oxigênio de pico, valores basais de função pulmonar ou sintomas de asma relatados. A carga de treinamento semanal foi significativamente menor nos atletas com broncoespasmo induzido por exercício do que naqueles sem esse diagnóstico. **Conclusões:** Nesta amostra de corredores de longa distância brasileiros, a prevalência de broncoespasmo induzido por exercício foi alta.

Descritores: Atletas; Asma induzida por exercício; Teste de esforço.

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Introduction

Exercise-induced bronchoconstriction (EIB) is characterized by a transient narrowing of the airways during and (more often) after strenuous physical effort.[1] Although it occurs predominantly in individuals with asthma or atopy,[2,3] EIB has been frequently observed in endurance athletes, especially long-distance runners.[4,5] This relatively high prevalence of EIB in athletes might be due to exercise-related factors, such as hyperventilation, prolonged exposure to allergens or bronchial irritants, and excessive inhalation of cold dry air.[6]

Several studies have reported that the prevalence of EIB, which ranges from 3.7% to 60%, is higher in elite athletes than in the general population.[7,8] This discrepancy can be partly explained by the type of sport practiced, the environmental conditions, and the method used in order to diagnose EIB.[9] In addition, in various studies investigating the prevalence of EIB in athletes, the training load has not been taken into account. For example, hyperventilation during training, together with the inhalation of irritants, can contribute to the development of respiratory disorders in elite athletes. It has been recently demonstrated that training can contribute to the development of airway hyperresponsiveness in elite athletes.[10]

The methods used in order to identify EIB are critical to making an accurate diagnosis. According to the International Olympic Committee, the eucapnic voluntary hyperpnea (EVH) test is the most sensitive method for identifying EIB in athletes.[11] This challenge test indirectly causes bronchial smooth muscle contraction by releasing inflammatory mediators.[12] The hyperosmolar stimulus induced by EVH and the subsequent airway injury induced by the high ventilation rate are considered to reflect what occurs during strenuous exercise.[13,14] The EVH test was developed in order to simulate the effects that ventilation at high flow rates has on the airway surface liquid, creating a drying and osmotic effect.[15]

Objective documentation of asthma or EIB as a prerequisite for an athlete to be allowed to use inhaled β_2 agonists was first introduced at the 2002 Winter Olympic Games. Although the use of albuterol and salmeterol in sports has recently been permitted, all other inhaled β_2 agonists remain prohibited.[16] Studies have suggested that exercise-related respiratory symptoms, as reported by elite athletes, are poor predictors of EIB and, therefore, should not be the sole basis for prescribing medications.[4,15] Interestingly, the International Olympic Committee has reported that the notification of β_2 agonist use by athletes correlates with the prevalence of asthma symptoms in all countries except Brazil; although the country ranks 8th among those where the prevalence of asthma is highest, only 0.7% of Brazilian athletes have reported using β_2 agonists.[17] This suggests that the prevalence of EIB in Brazilian athletes is underestimated.

To our knowledge, there are no studies in the literature evaluating the prevalence of EIB in Brazilian athletes. Therefore, the main objective of the present study was to determine the prevalence of EIB among elite long-distance runners in Brazil and whether there is a difference in the training loads among athletes with and without EIB.

Methods

We recruited 86 male athletes from among those in the elite category of the most prestigious long-distance street race in Brazil, known as *Corrida de São Silvestre*, which is held in the city of São Paulo every December 31st. In order to take part in the elite category, male athletes have to prove, with documentation, that they can run either a half marathon in no longer than 66 min or a full marathon in no longer than 138 min. During packet pick-up in the week prior to the race, elite male runners were informed of the objective of the study and were invited to leave their phone numbers for future contact. Thirty days after the race, 86 athletes were contacted, and 20 accepted to take part in the study. The reasons why the remaining 66 athletes declined to participate in the study included living far from the city of São Paulo, in 42; not having time to participate, in 14; and a lack of interest, in 10. The inclusion criteria were being a Brazilian male; having a peak oxygen consumption (VO_2) $\geq$ 65 $mL \cdot kg^{-1} \cdot min^{-1}$,[18] as confirmed by cardiopulmonary exercise testing (described below); and having no history of cardiopulmonary disease. The exclusion criteria were being unwilling to perform spirometry or the EVH test and being under treatment with asthma medications. All of the athletes who agreed to participate in the study gave written informed consent prior to the enrollment in the study. The clinical protocol was approved by the local human research ethics committee.

The present study was performed in accordance with recognized ethical standards, as well as with national and international laws.[19]

This was a cross-sectional study consisting of two visits on different days, with an interval of two weeks between the visits. In the first visit, all of the participants completed the International Study of Asthma and Allergies in Childhood (ISAAC) questionnaire on asthma symptoms, as well as a questionnaire to quantify the training load. In addition, the physical characteristics of the athletes were determined, and pulmonary function was assessed at rest, being immediately followed by a cardiopulmonary exercise test to determine peak VO_2. In the second visit, the participants were submitted to pulmonary function testing prior to and after EVH challenge. Those with a fall ≥ 10% in FEV_1 after EVH challenge were classified as testing positive for EIB (EIB+), whereas those with a fall < 10% in FEV_1 after EVH challenge were classified as testing negative for EIB (EIB−).[20]

Peak VO_2 was determined by treadmill ramp protocol cardiopulmonary exercise testing until exhaustion. The athletes were advised to refrain from coffee, caffeinated beverages, alcohol, and physical exercise 24 h prior to the test. Blood pressure, HR, and electrocardiographic activity were continuously monitored with an electrocardiogram, whereas ventilation, VO_2, carbon dioxide output, and oxygen pulse were monitored with a metabolic cart and a pneumotachograph (229 Vmax™; SensorMedics, Yorba Linda, CA, USA). Gas fractions were analyzed with oxygen and carbon dioxide analyzers calibrated with standard gases of known concentrations. The athletes had to achieve at least 95% of the age-predicted maximal HR[21] and a respiratory exchange ratio > 1.15 at peak physical exertion.[22]

All of the participants underwent pulmonary function testing with a computerized pneumotachograph spirometer (SensorMedics), in accordance with the American Thoracic Society recommendations.[23] The maximum fall in FEV_1 from the baseline (pre-EVH) value was calculated by the following formula, expressed in percentage:

$$[(\text{pre-EVH } FEV_1 - \text{lowest post-EVH } FEV_1) \div (\text{pre-EVH } FEV_1)] \times 100$$

Pulmonary function test results were compared with the predicted reference values for Brazilian adults.[24]

The EVH test was used in order to identify EIB, having been performed with the abovementioned metabolic cart and pneumotachograph (SensorMedics). The equipment was calibrated with a 3-L syringe prior to each test, and the software allowed us to monitor minute ventilation in real time. All of the participants inhaled a cold, dry gas mixture (5% carbon dioxide and 20.9% oxygen) balanced with nitrogen. The participants were asked to take a deep breath in order to maintain a target minute ventilation of 30 times the FEV_1 for 6 min. The volume was monitored on the computer screen, and verbal encouragement was given in case the minute ventilation fell below the target. A positive EVH test was defined as a ≥ 10% fall in FEV_1 from the baseline (pre-EVH) value.[11]

The ISAAC written questionnaire, previously validated for use in adults, was used in order to document asthma symptoms.[25] The ISAAC questionnaire comprises eight questions, each having a score ranging from 0 to 2, with a total score of 14. A score ≥ 5 indicates the presence of asthma symptoms.[25] In addition, all of the participants were asked four questions concerning their training habits, in order to obtain information regarding their training load.

Statistical analyses were performed with the Statistical Package for the Social Sciences, version 13.0 (SPSS Inc., Chicago, IL, USA). We used the Kolmogorov-Smirnov test and the Levene test in order to determine the homogeneity of variance between the groups. Numerical variables, such as age, body mass index, peak VO_2, pulmonary function parameters, and weekly training load, were compared by the Student's t-test. The prevalence of EIB was expressed in percentage. Statistical significance was set at $p < 0.05$, and the numerical variables were expressed as mean ± SD.

Results

Of the 20 elite athletes evaluated, 5 were classified as EIB+. In the EIB+ group, post-EVH FEV_1 was significantly lower than baseline FEV_1 ($p < 0.05$), with peaks at 5 and 10 min (Figure 1). The anthropometric characteristics of the athletes, as well as peak VO_2 and baseline pulmonary function variables, are presented in Table 1. All of the individuals in the EIB+ group presented with cough after the EVH test, and 2 also presented with wheezing. Interestingly, cough was also observed in 4 individuals in the EIB−

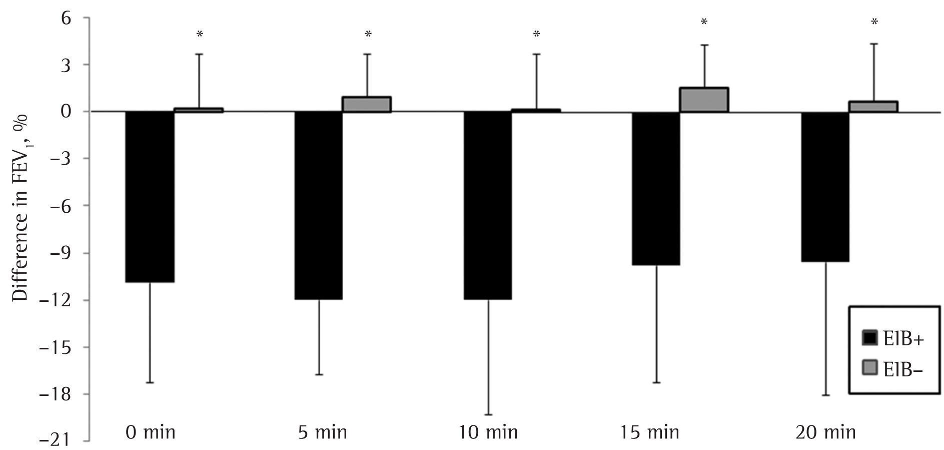

Figure 1 - Difference (in %) between baseline FEV_1 and FEV_1 at different time points after eucapnic voluntary hyperpnea challenge in the groups of athletes with and without exercise-induced bronchoconstriction (EIB+ and EIB−, respectively). A fall of at least 10% in FEV_1 after the EVH test is diagnostic of EIB. *$p < 0.05$.

group. During the EVH test, all of the athletes were able to maintain the target ventilation for 6 min, and there was no difference between the EIB+ and EIB− groups (124.5 ± 12.6 L/min vs. 122.8 ± 10.7 L/min; p = 0.8). None of the athletes had a score ≥ 5 (indicative of asthma symptoms) on the ISAAC questionnaire (Table 2). The weekly training load was found to be lower in the athletes in the EIB+ group than in those in the EIB− group (p < 0.05; Table 2). Regarding the training habits, the average running distance covered per week was the only parameter that showed a statistically significant difference between the EIB + and EIB− groups (Table 2).

Discussion

The objective of the present study was to evaluate the prevalence of EIB in elite long-distance runners in Brazil. Of the 20 runners under study, 5 (25%) tested positive for EIB, despite having no history of pulmonary dysfunction or asthma symptoms. Although peak VO_2 was found to be similar between the EIB+ and EIB− groups, the running distance covered per week was significantly shorter in the former.

In our study, 25% of the elite long-distance runners presented with EIB after the EVH test, which suggests a disparity between our results

Table 1 - Baseline anthropometric data, peak oxygen consumption, and baseline pulmonary function parameters in the athletes with and without exercise-induced bronchoconstriction.[a]

Variable	Total (n = 20)	EIB+ (n = 5)	EIB− (n = 15)	p
Age, years	30.5 ± 5.2	29.0 ± 5.0	31.1 ± 5.3	0.45
BMI, kg/m²	20.8 ± 1.6	20.6 ± 2.2	20.8 ± 1.5	0.80
Peak VO_2, $mL \cdot kg^{-1} \cdot min^{-1}$	63.8 ± 5.6	63.4 ± 9.3	64.0 ± 4.1	0.83
FEV_1, L	4.03 ± 0.52	3.86 ± 0.40	4.10 ± 0.56	0.38
FEV_1, % of predicted	101.0 ± 12.5	98 ± 8.4	103.0 ± 13.0	0.37
FVC, L	4.60 ± 0.50	4.38 ± 0.67	4.68 ± 0.44	0.25
FVC, % of predicted	98.3 ± 8.9	94.0 ± 11.1	100.0 ± 8.0	0.23
FEV_1/FVC ratio	86.2 ± 7.9	86.0 ± 6.6	86.3 ± 8.5	0.89
FEV_1/FVC ratio, % of predicted	100.4 ± 8.4	98.0 ± 3.3	101.0 ± 9.6	0.12
$FEF_{25-75\%}$, L/s	5.11 ± 1.20	4.67 ± 1.32	5.26 ± 1.19	0.36
$FEF_{25-75\%}$, % predicted	110 ± 24	104 ± 25	112 ± 24	0.55

EIB: exercise-induced bronchoconstriction; BMI: body mass index; and VO_2: oxygen consumption. [a]Values expressed as mean ± SD.

Table 2 - Asthma symptoms and training habits in the athletes with and without exercise-induced bronchoconstriction.[a]

Variable	EIB+ (n = 5)	EIB− (n = 15)	p
Having asthma symptoms, n[b]	0	0	1.0
Years running long distance	7.5 ± 3.9	8 ± 5.7	0.85
Average n of h/week spent running	10.6 ± 1.3	11.7 ± 2.5	0.37
Average running distance covered per week, km	80 ± 23.4	115 ± 26.1	0.01
n days/week running	6.2 ± 0.4	6.3 ± 0.5	0.59

EIB: exercise-induced bronchoconstriction. [a]Values expressed as mean ± SD. [b]International Study of Asthma and Allergies in Childhood questionnaire score ≥ 5.

and those reported in a study involving Brazilian Olympic athletes (prevalence of EIB, 0.7%).[17] In our opinion, there are two possible explanations for such a discrepancy. First, the EVH test, used in the present study in order to diagnose EIB, is not routinely performed in athletes in Brazil, which might explain the small number of athletes who reported using β_2 agonists in that study.[17] Second, Brazilian athletes do not always seek medical attention for respiratory problems, either because they are unaware that they have such problems or because they mistake respiratory symptoms for difficulty breathing due to heavy physical exertion. We cannot compare our findings with those of other, similar, studies conducted in Brazil, because none of those studies evaluated the prevalence of EIB in Brazilian runners. However, because we used the EVH test, which is the gold standard for the diagnosis of EIB, we can hypothesize that the prevalence of EIB in elite Brazilian athletes is underestimated. There are studies suggesting that the prevalence of EIB in winter sports athletes ranges from 17% to 25%.[26,27] Interestingly, the prevalence of EIB in our athletes was found to be as high as that reported in winter sports athletes. Although it is impossible to explain the high prevalence of EIB in our study, we can speculate that, in winter sports athletes, EIB is due to the inhalation of cold air, whereas, in our athletes, EIB is due to environmental conditions, such as high levels of air pollution.

Although all of the EIB+ athletes in the present study presented with cough after the EVH test, none had reported exercise-related respiratory symptoms prior to the test. Our results are in agreement with those of other studies, suggesting that athletes do not easily perceive or recognize respiratory symptoms.[26,28] In our study, none of the athletes reported asthma symptoms when answering the ISAAC questionnaire; this suggests that respiratory symptoms are poor predictors of EIB,[26,29] which reinforces the need to perform the EVH test in elite athletes performing aerobic exercise in order to document EIB. Symptoms reported in questionnaires alone are likely to provide a limited perspective, the agreement between self-reported symptoms and objective measurements of airway dysfunction being poor.[4]

There is evidence suggesting that, in athletes, longer periods of aerobic training translate to a greater likelihood of developing EIB.[14] In addition, EIB in athletes without asthma is a distinct entity from that in those with asthma. Therefore, it is possible that two different types of EIB occur in athletes: EIB that is due to high-intensity, long-term endurance training; and EIB that is due to asthma, being elicited by increased ventilation.[30] However, this hypothesis needs further investigation.

In the present study, the difference between EIB+ and EIB− athletes cannot be explained by the history of training, which was similar in the two groups (mean, 8 years; Table 2). Surprisingly, the athletes in the EIB+ group reported covering a shorter running distance during their training than did those in the EIB− group. This might be due to ventilatory limitation (bronchial obstruction) in the athletes in the EIB+ group; however, in the present study, this aspect was not assessed. It is of note that peak VO_2 values were similar between the two groups of athletes, which suggests that EIB was not due to a lack of fitness. Our results do not allow us to establish a cause-and-effect relationship between the training load and the occurrence of EIB, further studies being therefore required.

This is the first study to assess the prevalence of EIB in Brazilian runners. The relevance of our study lies in the fact that the number of runners in Brazil has been increasing, as well as in the fact that, in five years' time, Brazil will be hosting the two most important sports events in the world, namely the FIFA World Cup and the Olympic Games. Therefore, athletes and sports-related workers should be aware of all of the issues related to the performance of athletes.

The present study has some limitations, which should be noted. First, our sample was small and might not be truly representative of the population of elite Brazilian runners; however, in most of the studies in which EVH challenge was used in order to evaluate EIB in elite athletes, the sample size was similar to ours.[7,9] Second, it is difficult to evaluate elite athletes because they are constantly required to maintain training; therefore, they are seldom interested in taking part in studies that are not specifically related to physical performance, and most of them claim that they cannot participate in such studies because of their training and competition schedules. In the present study, we found that the athletes were concerned about having EIB and the consequences thereof, including medical treatment and the impact of EIB on their physical performance.

In conclusion, the prevalence of EIB in our sample of elite Brazilian runners was high. However, this was unrelated to the presence of asthma symptoms. Further studies should be carried out in order to establish the relationship between the occurrence of EIB and the training load of athletes.

References

1. Anderson SD, Daviskas E. The mechanism of exercise-induced asthma is ... J Allergy Clin Immunol. 2000;106(3):453-9. PMid:10984363. http://dx.doi.org/10.1067/mai.2000.109822
2. McFadden ER Jr. Exercise-induced airway obstruction. Clin Chest Med. 1995;16(4):671-82. PMid:8565407.
3. Virant FS. Exercise-induced bronchospasm: epidemiology, pathophysiology, and therapy. Med Sci Sports Exerc. 1992;24(8):851-5. PMid:1406168.
4. Holzer K, Brukner P. Screening of athletes for exercise-induced bronchoconstriction. Clin J Sport Med. 2004;14(3):134-8. PMid:15166901. http://dx.doi.org/10.1097/00042752-200405000-00005
5. Lecomte J. Asthma and exercise [Article in French]. Rev Med Brux. 2002;23(4):A206-10. PMid:12422436.
6. Parsons JP, Mastronarde JG. Exercise-induced bronchoconstriction in athletes. Chest. 2005;128(6):3966-74. PMid:16354868. http://dx.doi.org/10.1378/chest.128.6.3966
7. Sallaoui R, Chamari K, Chtara M, Alaranta A, Manai Y, Ghedira H, et al. Asthma in Tunisian elite athletes. Int J Sports Med. 2007;28(7):571-5. PMid:17436195. http://dx.doi.org/10.1055/s-2007-964838
8. Weiler JM, Metzger WJ, Donnelly AL, Crowley ET, Sharath MD. Prevalence of bronchial hyperresponsiveness in highly trained athletes. Chest. 1986;90(1):23-8. PMid:3522119. http://dx.doi.org/10.1378/chest.90.1.23
9. Holzer K, Douglass JA. Exercise induced bronchoconstriction in elite athletes: measuring the fall. Thorax. 2006;61(2):94-6. PMid:16443702 PMCid:2104581. http://dx.doi.org/10.1136/thx.2005.049031
10. Bougault V, Turmel J, Boulet LP. Airway hyperresponsiveness in elite swimmers: is it a transient phenomenon? J Allergy Clin Immunol. 2011;127(4):892-8. PMid:21167573. http://dx.doi.org/10.1016/j.jaci.2010.11.003
11. Anderson SD, Fitch K, Perry CP, Sue-Chu M, Crapo R, McKenzie D, et al. Responses to bronchial challenge submitted for approval to use inhaled beta2-agonists before an event at the 2002 Winter Olympics. J Allergy Clin Immunol. 2003;111(1):45-50. PMid:12532095. http://dx.doi.org/10.1067/mai.2003.1
12. Rundell KW, Anderson SD, Spiering BA, Judelson DA. Field exercise vs laboratory eucapnic voluntary hyperventilation to identify airway hyperresponsiveness in elite cold weather athletes. Chest. 2004;125(3):909-15. PMid:15006949. http://dx.doi.org/10.1378/chest.125.3.909
13. Anderson SD, Kippelen P. Airway injury as a mechanism for exercise-induced bronchoconstriction in elite athletes. J Allergy Clin Immunol. 2008;122(2):225-35; quiz 236-7. PMid:18554705. http://dx.doi.org/10.1016/j.jaci.2008.05.001
14. Langdeau JB, Boulet LP. Prevalence and mechanisms of development of asthma and airway hyperresponsiveness in athletes. Sports Med. 2001;31(8):601-16. PMid:11475322. http://dx.doi.org/10.2165/00007256-200131080-00005
15. Anderson SD, Argyros GJ, Magnussen H, Holzer K. Provocation by eucapnic voluntary hyperpnoea to identify exercise induced bronchoconstriction. Br J Sports Med. 2001;35(5):344-7. PMid:11579071 PMCid:1724385. http://dx.doi.org/10.1136/bjsm.35.5.344
16. World Anti Doping Agency [homepage on the Internet]. Montreal: World Anti Doping Agency. [cited 2011 Sep 5]. The 2011 Prohibited List – International Standard [Adobe Acrobat document, 9p.]. Available from: http://www.wada-ama.org/Documents/World_Anti-Doping_Program/WADP-Prohibited-list/To_be_effective/WADA_Prohibited_List_2011_EN.pdf
17. Fitch KD, Sue-Chu M, Anderson SD, Boulet LP, Hancox RJ, McKenzie DC, et al. Asthma and the elite athlete: summary of the International Olympic Committee's consensus conference, Lausanne, Switzerland, January 22-24, 2008. Allergy Clin Immunol. 2008;122(2):254-60, 260.e1-7.
18. Azevedo LF, Brum PC, Rosemblatt D, Perlingeiro Pde S, Barretto AC, Negrão CE, et al. Cardiac and metabolic characteristics in long distance runners of sport and exercise cardiology outpatient facility of a tertiary hospital. Arq Bras Cardiol. 2007;88(1):17-25. PMid:17364113. http://dx.doi.org/10.1590/S0066-782X2007000100003
19. Harriss DJ, Atkinson G. International Journal of Sports Medicine - ethical standards in sport and exercise science research. Int J Sports Med. 2009;30(10):701-2. PMid:19809942. http://dx.doi.org/10.1055/s-0029-1237378
20. Eliasson AH, Phillips YY, Rajagopal KR, Howard RS. Sensitivity and specificity of bronchial provocation

testing. An evaluation of four techniques in exercise-induced bronchospasm. Chest. 1992;102(2):347-55. PMid:1643912. http://dx.doi.org/10.1378/chest.102.2.347

21. Karvonen MJ, Kentala E, Mustala O. The effects of training on heart rate; a longitudinal study. Ann Med Exp Biol Fenn. 1957;35(3):307-15. PMid:13470504.
22. Rodgers GP, Ayanian JZ, Balady G, Beasley JW, Brown KA, Gervino EV, et al. American College of Cardiology/American Heart Association Clinical Competence statement on stress testing: a report of the American College of Cardiology/American Heart Association/American College of Physicians--American Society of Internal Medicine Task Force on Clinical Competence. J Am Coll Cardiol. 2000;36(4):1441-53. http://dx.doi.org/10.1016/S0735-1097(00)01029-9
23. Crapo RO, Casaburi R, Coates AL, Enright PL, Hankinson JL, Irvin CG, et al. Guidelines for methacholine and exercise challenge testing-1999. This official statement of the American Thoracic Society was adopted by the ATS Board of Directors, July 1999. Am J Respir Crit Care Med. 2000;161(1):309-29. PMid:10619836.
24. Pereira CA, Sato T, Rodrigues SC. New reference values for forced spirometry in white adults in Brazil. J Bras Pneumol. 2007;33(4):397-406. PMid:17982531. http://dx.doi.org/10.1590/S1806-37132007000400008
25. Maçãira EF, Algranti E, Stelmach R, Ribeiro M, Nunes MP, Mendonça EM, et al. Determining the score and cut-off point that would identify asthmatic adults in epidemiological studies using the asthma module of the International Study of Asthma and Allergies in Childhood questionnaire. J Bras Pneumol. 2005;31(6):477-85.
26. Hull JH, Hull PJ, Parsons JP, Dickinson JW, Ansley L. Approach to the diagnosis and management of suspected exercise-induced bronchoconstriction by primary care physicians. BMC Pulm Med. 2009;9:29. PMid:19527498 PMCid:2702295. http://dx.doi.org/10.1186/1471-2466-9-29
27. Uçok K, Dane S, Gökbel H, Akar S. Prevalence of exercise-induced bronchospasm in long distance runners trained in cold weather. Lung. 2004;182(5):265-70. PMid:15742238. http://dx.doi.org/10.1007/s00408-004-2503-6
28. Helenius IJ, Tikkanen HO, Haahtela T. Occurrence of exercise induced bronchospasm in elite runners: dependence on atopy and exposure to cold air and pollen. Br J Sports Med. 1998;32(2):125-9. PMid:9631218 PMCid:1756081. http://dx.doi.org/10.1136/bjsm.32.2.125
29. Pearce N, Sunyer J, Cheng S, Chinn S, Björkstén B, Burr M, et al. Comparison of asthma prevalence in the ISAAC and the ECRHS. ISAAC Steering Committee and the European Community Respiratory Health Survey. International Study of Asthma and Allergies in Childhood. Eur Respir J. 2000;16(3):420-6. PMid:11028654. http://dx.doi.org/10.1183/9031936.00.16337700
30. Bergeron C, Boulet LP. Structural changes in airway diseases: characteristics, mechanisms, consequences, and pharmacologic modulation. Chest. 2006;129(4):1068-87. PMid:16608960. http://dx.doi.org/10.1378/chest.129.4.1068

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