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Original Research

Exercising Blood Gas Analysis, Dynamic Upper Respiratory Tract Obstruction, and Postexercising Bronchoalveolar Lavage Cytology—A Comparative Study in Poor Performing Horses

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ABSTRACT

Respiratory abnormalities are common causes of decreased performance in horses presumably because of impaired pulmonary gas exchange. The objectives of the present study were to describe respiratory abnormalities in poorly performing horses and to investigate the relationships between dynamic upper respiratory tract (URT) video-endoscopy, postexercising bronchoalveolar lavage (BAL) cytology, and exercising arterial blood gas analysis. Medical records of 93 horses with exercise intolerance, which presented for treadmill evaluation, were reviewed. Relationships between horse demographics, treadmill endoscopic findings, exercising blood gas values, and BAL cytology results were examined. A total of 25 (27%) horses had a URT obstruction and 91 (98%) horses had abnormal BAL cytology; 73 (78%) had evidence of inflammatory airway disease (IAD) and 83 (89%) had exercise-induced pulmonary hemorrhage (EIPH). In all, 39 (42%) horses had abnormal blood gas values. Dynamic URT obstruction was significantly associated with exercising hypoxemia ($P = .036$). There were no significant relationships between gas exchange and IAD or between EIPH. Out of 24 (26%) horses with combined URT obstruction and abnormal BAL, horses with URT obstruction and EIPH were more likely to be hypoxic during exercise ($P = .037$). It was concluded that horses with dynamic URT abnormalities are likely to have exercising hypoxemia. Although IAD and EIPH were commonly indentified in poor performers, they were not significantly associated with abnormal exercising blood gas analysis.

1. Introduction

Respiratory diseases have been associated with decreased performance and exercise intolerance in horses, presumably because of impaired gas exchange. However, clinical signs are often nonspecific, subclinical, or only apparent under maximal exertion, which pose a diagnostic challenge under normal resting conditions. Treadmill testing is a valuable diagnostic tool for horses with decreased athletic ability because it facilitates examination of the respiratory system during exercise. The use of exercising upper airway endoscopy has been well documented and numerous dynamic upper respiratory tract (URT) obstructions have been identified [1-5]. Exercising arterial blood gases has been used to assess pulmonary gas exchange and it helps to determine whether diseases are associated with inadequate gas exchange. Previous reports indicate that URT obstructions can be associated with inadequate gas exchange [6-8].

Lower respiratory tract diseases such as exercise-induced pulmonary hemorrhage (EIPH) and inflammatory airway disease (IAD) are also common causes of poor athletic performance in horses [9-12]. EIPH is diagnosed either by observing the presence of blood in the upper

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airways after exercise or by detecting hemosiderophages in bronchoalveolar lavage (BAL) samples. IAD is characterized by a history of cough, excessive mucous, nasal discharge, poor performance, or prolonged recovery from exercise [9]. Despite the recognized importance of IAD in limiting performance, definitive criteria for diagnosis are variable. Visual evidence of increased tracheal secretions, cytological evidence of increased inflammatory cells in tracheal or bronchial secretions, and lung function testing have been used for diagnosis [9]. Reportedly, horses with EIPH or IAD can exhibit pulmonary gas exchange impairment [7,10,11].

Our hypothesis was that upper and lower airway diseases are common in horses with exercise intolerance and the affected horses would have impaired gas exchange during strenuous treadmill exercise. We previously examined the relationship between exercising arterial blood gas analysis and postexercise tracheal wash cytological findings in a group of horses with poor performance, but could not determine the effect of IAD on gas exchange [12]. However, the current American College of Veterinary Internal Medicine (ACVIM) Consensus Statement for IAD in horses [13] states that "the use of tracheal wash cytology is insufficient for the diagnosis of IAD." The purpose of this retrospective study was to examine the relationships between exercising arterial blood gas analysis and respiratory diseases using the current recommendations stated in the ACVIM Consensus Statement for IAD in horses undergoing comprehensive treadmill testing for evaluation of poor performance.

2. Materials and Methods

Medical records of horses that underwent high-speed treadmill (HSTM) exercise with a complaint of poor performance between October 2004 and June 2009 were reviewed. Before treadmill exercise, horses underwent a clinical examination including a lameness examination. Horses with significant lameness or evidence of a cardiac problem were excluded from the study. Only horses that had a comprehensive poor performance evaluation and were exercised at $\geq$8 m/s on the HSTM were included in the study. Comprehensive evaluation included all of the following: resting and exercising upper airway endoscopy, cardiac examination (pre- and postexercise echocardiogram and continuous exercising telemetric electrocardiogram), exercising arterial blood gas evaluation, postexercising BAL cytologic evaluation, and pre- and postexercise muscle enzyme measurements. Examinations and sampling were performed on the same day on an outpatient basis.

2.1. Exercise Test

Horses were first acclimated to the treadmill (Classic 4000 High-Speed Equine Treadmill; Walmanik International, Freedom, PA) during a training session. Standardbred horses were exercised with harness equipment used during a race. Thoroughbreds (TBs) and Warmbloods were exercised without a tack. After treadmill familiarization, horses were placed in a stall and rested 1 to 2 hours before HSTM examination. The warm-up consisted of exercise at approximately 7 m/s for 1,600 meters, followed by walking until the heart rate had decreased to $<$100 beats per minute. The treadmill was then stopped, a nose twitch placed, and a flexible endoscope (GIF-Q Gastroscope, CLV-U20 light source, CV-100 image processor; Olympus, Lake Success, NY) was passed up the right nasal passage until the tip was positioned just caudal to the guttural pouch openings. The endoscope was secured in position with Velcro, to the noseband of the halter and the twitch was removed. Exercising videoendoscopy was recorded in real time on a video recorder (SVO-9500MD Video Recorder; Sony Medical, Montvale, NJ). Horses were exercised at 8 to 13 m/s at an incline of 0° to 2°. Both speed and incline were dependent on the fitness level, ability, and mental aptitude of the horse. Horses were exercised for 3 to 4 minutes over approximately 2,400 meters with the goal of achieving a peak heart rate of a minimum of 200 beats per minute or until the horse could no longer keep pace with the treadmill speed. Treadmill intensity was decreased for horses that were struggling to complete the test. Exercising videoendoscopic recordings were reviewed in real time and in slow motion. Dynamic upper airway obstruction was determined by visual evidence of dynamic collapse of URT structures into the rima glottidis.

2.2. Arterial Blood Samples

Arterial blood samples were collected through a 20 G catheter (Abbocath-T, Abbott Ireland, Sligo, Ireland) placed in the transverse facial artery. Core body temperature was measured using an intravenous thermocouple probe (Physiotemp Type IT-14, Physiotemp Instruments Inc., Clifton, NJ) passed to the level of the right atrium through a 14 G catheter (Angiocath, Becton-Dickerson, Sandy, UT) inserted in the left jugular vein. Samples were collected anaerobically into heparinized syringes before exercise, immediately after warm-up, at 1-minute intervals during the exercise test and within 30 seconds after the completion of the exercise (to a maximum of seven samples). Samples were placed on ice immediately after collection and analyzed (CIBA-GEIGY 288 BG, Norwood, MA) within 30 minutes. Blood gas measurements were temperature-corrected. Sampling was obtained in a similar manner for control and clinical cases.

As previously described [6], the following equations, along with 95% confidence limits, were used to determine the range of normal exercising blood gas values: partial pressure of arterial oxygen (PaO_2) = (114.2 $\pm$ 2.9) $-$ ([2.7 $\pm$ 0.4] $\times$ [running speed]) and partial pressure of arterial carbon dioxide ($PaCO_2$) = (35.5 $\pm$ 1) + ([0.5 $\pm$ 0.1] $\times$ [running speed]). The equations are the result of linear regression analysis of arterial blood gases from control horses versus treadmill speed [6,12]. Control horses consisted of 163 physically fit TB horses that were found to be clinically healthy, based on physical examination, resting and exercising upper airway endoscopic examination, cardiac examination including exercising electrocardiogram, and lameness examination [12]. Exercising blood gas values of the poorly performing horses were compared with the expected normal blood gas values (Fig. 1). Horses were considered to have more severe exercising hypoxemia if the exercising PaO_2 value was less than the normal exercising PaO_2 value, and to have more severe