

Changes in Arterial Oxygen Tension in COPD Horses after Reduction of Exposure to Dust in the Feed and Environment

C. KVART, J. CARLSTEN, L. DAHL and L. RYDEN

Department of Medicine 1, Faculty of Veterinary Medicine, Swedish University of Agricultural Sciences, S-750 07 Uppsala, Sweden.

Summary

Seven horses afflicted by chronic obstructive pulmonary disease (COPD) were examined twice. Once when they were kept on straw bedding and fed hay (period A) and once when they had been fed silage and kept in an optimal environment for COPD prophylaxis for 1–3 months (period B). The following parameters were studied at rest and during a standardized exercise tolerance test on an inclined treadmill: arterial oxygen tension (PaO_2), arterial carbon dioxide tension ($PaCO_2$), blood lactate, respiratory rate and heart rate. Lung biopsies were obtained percutaneously directly after each test period. Only one parameter was significantly different between periods A and B. PaO_2 was greater at rest and at treadmill speeds up to 5 m/sec when the horses were kept on COPD prophylaxis. Above this speed, the difference in PaO_2 between periods A and B decreased and was insignificant at 9 m/sec. The greatest difference in PaO_2 between the two examinations occurred at 2 m/sec. There was no significant difference between the values at 0.5 and 2 minutes after exercise.

Index terms: Arterial carbon dioxide tension; blood lactate; exercise tolerance; environment.

Introduction

Abnormally low levels of arterial oxygen tension in the resting horse are used as one criterion for diagnosis of chronic obstructive pulmonary disease (COPD) (McPherson *et al.*, 1978). This clinical test can discriminate between healthy individuals and those severely affected by COPD but is less helpful for detection of milder cases (McPherson *et al.*, 1978). One reason for this is that many COPD horses, as well as normal subjects, have a substantial capacity to increase the resting PaO_2 depending on the amount of induced psychologic stress at the moment of sample collection (L. Ryden and C. Kwart unpublished data).

Bergsten (1974) determined PaO_2 in normal horses and horses with chronic alveolar emphysema during rest and exercise. Significantly lower mean values were found for the latter group in both situations. Since the COPD horses in Bergsten's study were

only examined once at one velocity on the treadmill (4 m/sec), the following study was designed to investigate the influence of an improved environment on indicators of exercise tolerance at different treadmill speeds.

Materials and Methods

Seven Standardbred horses weighing from 381 to 560 kg, with clinical COPD, were studied. They were affected mildly but considered capable of running up to 9 m/sec on an inclined treadmill (6.25%). The diagnosis was based on clinical signs such as chronic coughing, increased respiratory efforts, endoscopic evidence of increased tracheobronchial secretions and a history of poor work performance.

Arterial blood samples were withdrawn from either the facial or carotid artery into heparinized 2-ml syringes. The facial artery was percutaneously catheterized under local anesthesia with a 3.6 cm long and 2 mm wide teflon indwelling cannula (Branüle cannulas B. Braun Melsungen AG, West Germany) on ten occasions. When this failed, the carotid artery was punctured with a 6.5 cm long and 2.5 mm wide Teflon indwelling cannula. At least half the length of a 90 cm long guide wire was introduced through the teflon cannula after withdrawal of the internal needle. The Teflon cannula was then removed and another 17.5 cm long and 2.7 mm wide vascular dilator (Arrow International Inc. Pennsylvania USA) was introduced over the guide wire, the guide wire withdrawn and the dilator used for blood sampling. An 8 French microtip catheter (Millar instruments, Inc. Houston Texas USA) was introduced percutaneously into the pulmonary artery and used for central venous blood sampling.

The catheters were sutured to the skin. Blood samples were drawn at rest and during the last 15 sec of exercise at each treadmill speed (2 min work/speed). The syringes were capped and stored in crushed ice until completion of exercise.

Blood gas partial pressures were determined using a commercial blood gas analyzer (ABL 3 Radiometer, Copenhagen, Denmark). Temperature corrections were based on measurement of rectal temperature. After deproteinization of samples blood lactate was assayed using the method by Boehringer Mannheim GMBH Diagnostica (Test combination number 124842). Exercise tolerance was determined as described by Persson (1967, 1983). Lung biopsies for histopathological examination were obtained within 24 hours of each exercise test using a method of Dahl *et al.* (1987).

Each horse was tested twice, once while on straw bedding and receiving hay (period A) and once after having been in an improved environment and receiving silage (Horsehage Sollebolagen, Uddevalla, Sweden) for one to three months. An improved environment was achieved by keeping the horses on shredded paper bedding in separate stables with optimal ventilation. The horses were considered to be unaffected by COPD when respiratory effort appeared normal and resting PaO₂ was above 11.5 kPa.

Means and standard deviations were calculated for all values at rest and each treadmill speed. Measurement periods were compared by paired t-test.

Results

Resting and exercise data are illustrated in Table 1. Only PaO₂ showed a statistically significant difference ($P < 0.0025$) between the two periods. The mean values of PaO₂ were significantly higher at rest and at treadmill speeds up to 5 m/sec at period B when the horses were kept in an improved environment. Above this speed, the PaO₂ differ-

TABLE 1. Mean values and standard deviations (SD) from seven horses when examined after stabling in improved environment for one to three months (period B) and after exposure to straw and hay (period A).

Speed m/sec	STOP										
	0	2	3	4	5	6	7	8	9	0.5 min	2 min
PaO ₂ (period B)	13.8* ± 1.2	14.4* ± 2.3	13.5* ± 2.6	12.9† ± 2.6	11.8† ± 2.4	10.8* ± 2.4	9.8* ± 2.0	9.0 ± 1.5	8.4 ± 1.0	13.9 ± 1.8	15.4 ± 1.5
PaO ₂ (period A)	11.0 ± 1.9	10.4 ± 1.9	10.4 ± 2.2	9.8 ± 1.8	9.2 ± 1.9	8.9 ± 2.0	8.2 ± 1.6	8.1 ± 1.5	7.7 ± 1.1	12.7 ± 1.5	14.3 ± 2.1
PaCO ₂ (period B)	5.9 ± 0.7	5.9 ± 0.6	5.8 ± 1.0	5.9 ± 1.0	6.2 ± 1.5	6.9 ± 1.9	6.8 ± 2.3	7.0 ± 2.7	6.0 ± 0.5	4.2 ± 0.6	3.1 ± 0.7
PaCO ₂ (period A)	6.2 ± 0.4	5.8 ± 0.8	6.0 ± 0.9	6.2 ± 1.2	6.5 ± 1.6	6.8 ± 2.1	7.2 ± 2.2	7.2 ± 2.4	6.3 ± 0.3	5.2 ± 1.1	3.7 ± 1.0
Lactate (period B)	1.2 ± 0.3	1.3 ± 0.4	1.5 ± 0.4	1.4 ± 0.3	2.0 ± 1.0	2.4 ± 0.9	3.9 ± 1.8	6.6 ± 2.9	11.1 ± 2.8	13.0 ± 3.6	12.3 ± 2.6
Lactate (period A)	1.0 ± 0.4		1.3 ± 0.3	1.5 ± 0.3	1.8 ± 0.4	2.7 ± 1.0	4.5 ± 2.0	5.5 ± 1.5	10.3 ± 1.2	11.7 ± 1.9	11.5 ± 1.6
RR (period B)	31 ± 10.6	61 ± 22.4	72 ± 13.5	78 ± 10.3	90 ± 13.4	95 ± 16.0	102 ± 13.2	103 ± 12.5	109 ± 13.0	95 ± 18.0	99 ± 22.2
RR (period A)	28 ± 6.9	64 ± 14.2	85 ± 21.1	89 ± 20.4	95 ± 25.2	98 ± 22.6	107 ± 25.4	99 ± 22.2	99 ± 24.6	78 ± 19.7	89 ± 28.7
HR (period B)	36 ± 3.4	110 ± 15.8	133 ± 10.0	144 ± 9.9	162 ± 11.6	175 ± 10.2	189 ± 10.0	201 ± 10.4	211 ± 9.2		112 ± 12.3
HR (period A)	43 ± 16.9	102 ± 23.3	130 ± 16.3	147 ± 19.0	162 ± 21.6	173 ± 17.5	191 ± 13.2	205 ± 9.9	213 ± 10.4		110 ± 21.4

RR = respiratory rate (min⁻¹); HR = heart rate (min⁻¹); PaO₂ and PaCO₂ are a kPa, lactate in mmol/l. Data are means ± SD. Statistically significant differences between periods A and B are indicated; * = P < 0.05; † = P < 0.01.

ence between periods A and B decreased and was insignificant at 9 m/sec. The greatest difference in PaO₂ between the two examinations occurred at 2 m/sec. There was no significant difference between the values at 0.5 and 2 minutes after exercise (Fig. 1).

One horse was unable to run faster than 7 m/sec, after being exposed to straw and hay, but had no problems running 9 m/sec after being kept in the improved environment. Another horse could not exceed 8 m/sec in any of the tests. This horse also differed from the rest of the horses, showing lower PaO₂ values (≈5 kPa) and a progressive increase in PaCO₂ up to 12 kPa during exercise at 8 m/sec.

Evaluation of lung tissue morphology did not reveal any difference between samples taken during improved environment and during exposure to straw bedding and hay diet.

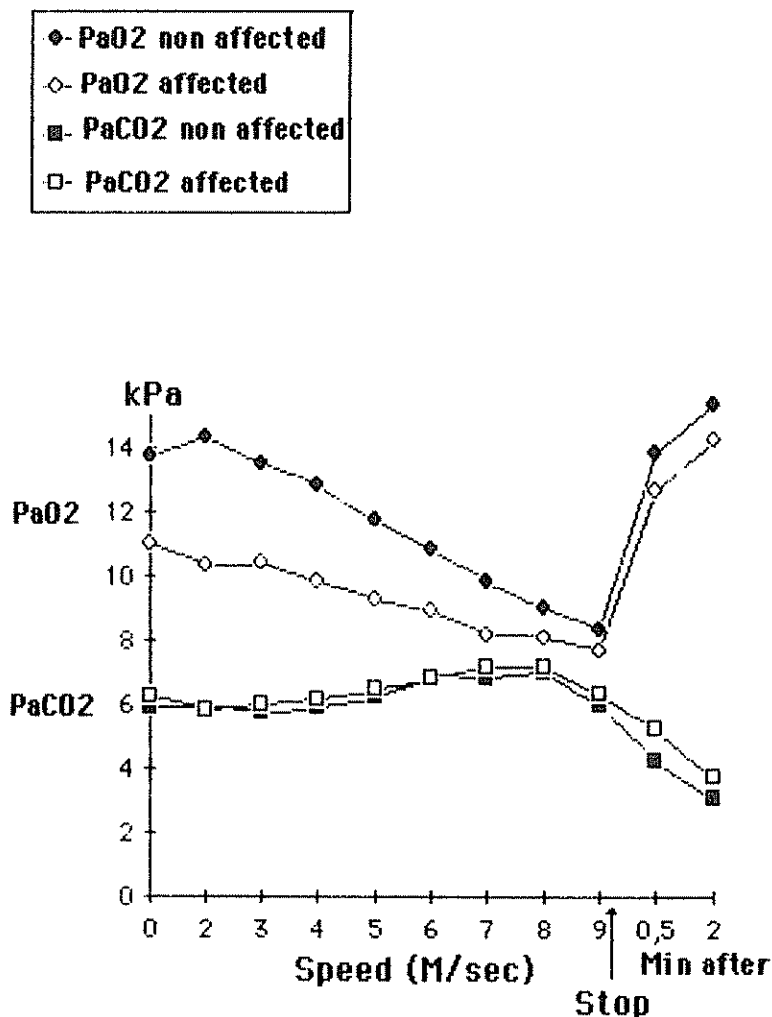


FIGURE 1. Mean values for PaO₂ and PaCO₂ from seven COPD horses examined with a standardized exercise tolerance test, during exposure to straw and hay (affected) and during improved environment ("nonaffected").

Samples of normal pulmonary tissue and lesions compatible with COPD were found in both groups.

Discussion

Interestingly, when the horses were kept in controlled environment, PaO_2 increased during the walk (2 m/sec), before it started to decrease with elevated speeds. This pattern was not seen when the horses were kept on straw and fed hay, where PaO_2 declined immediately after the start of exercise. This observation is in agreement with the findings of Littlejohn and Bowles (1981) who studied normal and COPD subjects. The greatest difference in PaO_2 between the two management periods also occurred at 2 m/sec treadmill speed.

Improved alveolar gas exchange at 2 m/sec (walking speed), is presumably responsible for these findings. Bronchodilation and higher pulmonary perfusion pressures may contribute to improved gas exchange at low velocities (2 m/sec) in those horses with improved lung-health by leading to improved matching of ventilation and perfusion. Because of their lung disease, at higher treadmill velocities these horses' PaO_2 began to decrease but at a lower rate than the more severely affected group.

Horses with COPD are usually capable of performing moderately demanding exercise but are also known to suffer from lack of stamina. COPD can exist in many different degrees and attempts for classification have been made (Gerber, 1973, Viel, 1984). Mild COPD can be difficult to diagnose, and many other diagnoses must be considered in horses with a history of reduced exercise tolerance. Collection of clinical data on the resting horse is often unrewarding in the individual horse. Psychological stress can cause the resting PaO_2 values to vary substantially (L. Ryden and C. Kvarn, unpublished data). The present study does however postulate that PaO_2 determined during walking exercise on a treadmill can increase the ability to diagnose mild COPD.

Determination of PaO_2 at 2 m/sec is also practical, as this speed only demands low treadmill capacity, is safe, and there is no need for body temperature correction of blood gas data.

Determination of PaCO_2 in resting horses is usually not helpful for clinical evaluation of COPD. During exercise however the PaCO_2 can discriminate between mild and more severe cases. If a significant progressive increase is found during exercise, as in one of the horses examined, the COPD must be considered more severe. A significantly higher PaCO_2 was found by Bergsten (1974) in horses with chronic alveolar emphysema compared to normals after 10 min exercise at a treadmill speed of 4 m/sec.

Comparison of the heart rate during exercise when the horses were "affected and nonaffected" by COPD showed no difference, which is in contrast to the observations of Persson (1968) and Littlejohn, *et al.* (1983). Both groups found an increase in heart rate in COPD horses compared to normals. A normal heart rate in COPD horses was also reported by Bergsten (1974). Impairment of gas exchange due to COPD is obviously not always compensated for by an increase in heart rate during exercise. One reason for the discrepancy in the results may be that heart rate is only elevated in horses with more severe forms of COPD. Therefore the pulse/work relationship expressed as the treadmill velocity corresponding to a heart rate of 200 (V_{200}) as described by Persson *et al.* (1983), also did not discriminate between the two management periods, because this parameter is based on heart rate.

No difference in respiratory rate at rest or during exercise was found between the two management periods which indicates that this parameter has too low a sensitivity to reveal pulmonary dysfunction of horses with mild or moderate COPD.

Blood lactates were unaltered between the two management periods. The equally unchanged heart rate indicates that no change occurred in arteriovenous oxygen difference between the management periods which may be the explanation.

The lack of histological differences in pulmonary biopsy samples from the two management periods indicates that this method of investigation is insensitive. It may be difficult to get a biopsy from a representative part of the lung parenchyma. More time may also be required to produce histological changes diagnostic of COPD. Bronchospasm may also be responsible for the observed blood gas changes.

Conclusions

Reduction of exposure to dust in the feed and environment, achieved by alterations in diet, bedding and ventilation, can improve the pulmonary gas exchange at rest and during exercise in COPD horses.

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Characteristics of Respiratory Airflow during Exercise in Horses with Reduced Performance due to Pulmonary Emphysema or Bronchitis

U. POLLMANN and H. HÖRNICKE

Universität Hohenheim, Institut für Zoophysiologie, D 7000 Stuttgart 70, West Germany.

Summary

The diagnostic relevance of several respiratory parameters was studied in three groups of riding horses: (I) four healthy horses, (II) five horses with chronic bronchitis, (III) four horses with bronchitis and pulmonary emphysema. They were lunged without rider (5 min walk, 5 min trot) because it was expected that the pneumotachogram would show flow limitations more clearly during exercise than at rest. Electrocardiogram and respiratory airflow were transmitted telemetrically. At all gaits, group I had the lowest and group III the highest heart rates at a given velocity. Tidal volumes and inspiratory flow rates increased in group order. The respiratory time quotient (TE/TI) was negatively correlated with respiratory frequency; in bronchitic horses (group II) it was lower at all respiratory frequencies. The diseased horses had flow maxima later during inspiration and earlier during expiration than normal horses. The reduction in volume and flow reserves were readily observed on flow-volume loops. We conclude that the exercise pneumotachogram gives information of diagnostic relevance.

Index terms. Chronic obstructive pulmonary disease; pneumotachogram; tidal volumes; respiratory time quotient; flow volume loops.

Introduction

Chronic obstructive pulmonary diseases (COPD) are major causes of reduced performance in horses and present considerable diagnostic difficulties (McPherson *et al.*, 1978). Because of the legal consequences of trading such horses, it is highly desirable to have objective methods to document the presence or absence of COPD in horses. Well established methods exist to measure functional parameters such as lung compliance, flow resistances and respiratory work using stationary equipment in horses at rest or after excitement (Spörri and Leemann, 1964; Gillespie *et al.*, 1966; Sasse, 1971; Willoughby and McDonnell, 1979). It is conceivable, however, that minor grades of disease which do not impair resting pulmonary ventilation may become apparent only during exercise.