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A RESTING AND DYNAMIC ENDOSCOPY AS DIAGNOSTIC TOOLS IN DECREASING TRAINING CAPACITY IN HORSES – A REVIEW

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Abstract

During the effort, when the need for oxygen increase, the respiratory frequency, heart rate, and cardiac output increase and a pool of erythrocytes from the spleen are ejected. Therefore, the evaluation of training capacity based on the changes in the heart rate and the blood-picture. Among the most common cause of decreasing training capacity and eliminating horses from sports training, the upper respiratory tract (RT) diseases are the second. The dynamic obstructions of upper RT such as recurrent laryngeal neuropathy (RLN) and dorsal displacement of the soft plate (DDSP) case of stenosis, occurring when the soft tissues in pharynx collapse due to the changing pressures in RT. Horses suspected of lowering sports performance due to upper RT disorders are examined using endoscopy: resting endoscopy, the high-speed treadmill endoscopy and the newest one, overground endoscopy are conducted. However, the accuracy of diagnosing dynamic changes in the pharynx increase, when the dynamic endoscopy is conducted. The overground endoscopy is considered the best diagnostic tool to detect and confirm RLN, DDSP and other dynamic upper RT disorders. It is significant in the aspect of pre-purchase examination, in particular in racehorses in which the frequency of occurring of these disorders is high.

Physiological background

Respiratory tract (RT) is an instrument for gas exchange. About 40–60 l of air per minute goes through horse's respiratory tracts when the horse is breathing during the rest. It can get to 40 times more air during intensive exertion – Table 1 – (DUCHARME et al. 1994, DUCHARME et al. 1999).

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Table 1
A comparison of respiratory parameters in healthy horses at rest and during strenuous exercise

Respiratory parameter	Rest	Strenuous exercise
Breathing frequency [breaths min^{-1}]*	10 to 15	120 to 150
Tidal volume [l]*	3 to 6	14 to 20
Minute ventilation [l min^{-1}]*	40 to 60	1500 to 2000
Peak inspiratory pharyngeal pressure [cm H_2O]**		-20 to -26
Peak expiratory pharyngeal pressure [cm H_2O]**		10 to 20
pO_2 [mm Hg]***	105 to ~110	69 to ~74

Data from: *AERTS et al. (2008), **DUCHARME et al. (1994), ***DUCHARME et al. (1999)

Beside gas exchange, RT also ensures proper pH in the organism (SANCHEZ et al. 2005). Each disorder that causes shrinking of the light of respiratory tracts will result in higher blood pressure and lower breathing efficiency. That is why, in order to maintain proper aerobic and training capacity, it is important to keep high larynx's throughput which allows efficient ventilation. During the exertion, lactates are accumulated and metabolic acidosis appears which can be partially compensated by the respiratory system. Despite the fact that horses have a very high tolerance when it comes to working in low-oxygen conditions, they do have their limits. In this case, measuring pO_2, pCO_2 and blood pH, before, immediately after and 30 minutes after finishing the training are also reliable for defining the training efficiency (BUTLER et al. 1993). Therefore, diseases of RT may affect this compensation processes leading to decreased training capacity. It is worth to mention that such diseases, after the orthopedic injuries, are the second most common reason for which horses are put away from the training (VAN ERK-WESTERGREN et al. 2013).

An indicators of training capacity

During the effort, the need for oxygen increases significantly. The organism tries to cover it up by increasing respiratory frequency, heart rate, and cardiac output as well as ejecting a pool of erythrocytes from the spleen to the bloodstream. Physical effort causes endogenous stress which leads to changes in the red cell system, changes in the concentration of lactic acid in blood and tissues and causes oxidative stress (ART and LEKEUX 2005). The previously mentioned changes are used in assessing exercise capacity of horses. To determine changes in the heart rate, pulse measurement is done right before the exertion and 15 minutes after. Horse's resting heart rate approximates from 20 to 48 beats per minute and in aerobic conditions, it goes up to 150 beats per minute. After 15 minutes the exercise is over, it should vary between 52 and 64 beats per minute if the training was done properly (AERTS et al. 2008). Nowadays, Holter ECG is used to monitor heartbeat which allows measuring myoelectric heart activity before, during and after the exertion. Additionally, hematological tests can be done to assess the exercise capacity, of which the best indicators are HGB (hemoglobin) and HCT (hematocrit) that provide information about oxygen volume in blood. After the exertion, HCT increases significantly because of spleen contraction and dehydration and should get back to normal level in about 30 minutes after the training. What is interesting, in well-trained horses and horses with outstanding sports predispositions high level of HGB and HCT can be observed (BURLIKOWSKA et al. 2015). Among biochemical tests, total protein (TP), lactic acid (LA), aspartate transaminase (AST) and creatine kinase (CK) concentrations give the information about the level of training and regenerative capabilities of the horse. TP indicates dehydration level caused by a noticeable increase in body temperature during exercise, whereas LA is a measure of working in low-oxygen conditions. Resting concentration of LA oscillates between 0.8–1.0 mmol l^{-1}, but after the race, it can raise up even to 30.0 mmol l^{-1} (AERTS et al. 2008). The significant increase in LA concentration may be observed only immediately after intense effort so that is why we might not spot in the next samples. Finally, the concentration of AST and CK indicates the muscles' damage degree (BUTLER et al. 1993).

The respiratory causes of decreasing training capacity

The recurrent laryngeal neuropathy (RLN) and dorsal displacement of the soft plate (DDSP) are the most commonly diagnosed disorders of upper RT. Both are the case of stenosis, occurring when the soft tissues in pharynx collapse due to the changing pressures in RT – Table 1 – (FRANKLIN 2008a). The shrinking of the diameter of upper RT changes partial pressure of blood gases, with a decrease of pO_2 and an increase of pCO_2 in arterial blood, and decreases training capacity (DURANDO et al. 2002). In both cases, the abnormal respiratory noises from upper RT occur, similar to other disorders such as subepiglottis cysts (SEC) or laryngeal dysplasia (LD) (FRANKLIN 2008a). In case of LD, the rostral displacement of palato-pharyngeal arch and right laryngeal haemiplegia or arytenoid cartilages deformations occur and the additional diagnostic tools such as endoscopy, ultrasonography, and MRI are necessary for proper diagnosis (GARRETT et al. 2009). However, recent studies have shown, that resting endoscopy is an insufficient tool for accurate differentiation of upper RT diseases (ELLIOT and CHEETHAM 2018, PARENTE 2018).

Recurrent laryngeal neuropathy

RLN is the most common form of laryngeal hemiplegia, when the demyelination of the recurrent laryngeal nerve, the longest nerve in a horse body, occurs (DUPUIS et al. 2012). Nerve damage causes muscles dysfunctions, especially the cricoarytenoideus muscle which is responsible for the abduction of arytenoids cartilages (RHEE et al. 2009). The following are mentioned among the most common reasons of RL: injuries, fungal infections of the guttural pouches, intoxications, mineral deficiencies and idiopathic causes (DART et al. 2005). They lead to progressive degenerative changes, laryngeal muscles atrophy, lack of abduction of arytenoid cartilage or limpness, and collapse of vocal folds when the pressure inside the respiratory tract is increased. As a consequence, a decrease of breathing efficiency appears along with turbulent airflow and characteristic wheezing sound (STICK and DERKSEN 2010).

RLN is more common in large breeds, with higher frequency in males than in females (GARRETT et al. 2009). DUPUIS et al. (2012) identified two regions of the horse genome responsible for predispositions for this neuropathy. The base of diagnosis includes 4-grade Havemayer scale (COLLINS et al. 2009), or rather 5-grade and 6-grade classification (DIXON et al. 2001), describing the degree of larynx impairment. At 1st grade, both arythenoid cartilage and vocal folds are symmetrical while resting as well as in the move. At 2nd grade, slight asymmetry of cartilage movement and vocal folds are visible; when a horse is in motion, with complete abduction. The 3rd grade is characterized by asynchronic and incomplete abduction, whereas the 4th grade by total larynx collapse. Such horses are qualified for laryngoplastic surgery (DIXON et al. 2001, COLLINS et al. 2009). Proper gradation becomes more difficult when the partial paralysis of larynx occurs and it collapses only in motion. Then the resting endoscopy examination turns out to be insufficient and dynamic endoscopy, on a treadmill or overground, is recommended (WOODIE 2011).

Dorsal displacement of the soft plate

Physiologically, the palate is located below epiglottis and separates airways from alimentary tract. DDSP consists in periodic or permanent displacement of the caudal part of soft palate above the epiglottis cartilage which causes disorder in airflow to larynx and trachea as well as appearing of abnormal breath sounds. The characteristic sound is caused by fluctuating caudal part of the soft palate when breathing out (FRANKLIN et al. 2003).

In a case of the intermittent DDSP, decreasing training capacity during exertion and dysphagia in resting occurs. The less advanced disorders consist only in lifting or fluctuation of the soft palate (ALLEN et al. 2007, BARAKZAI and DIXON 2011). Among the reasons of DDSP, too long palate, palate laxity caused by atony, diminished epiglottis, pharynx inflammation but also RLN or myopathy of pharynx muscles were reported (FRANKLIN et al. 2003). According to another hypothesis, a curb in horse's mouth may trigger a swallow reaction and an increase of saliva secretion which may lead to palate displacement. Palate displacement over the epiglottis can happen during intensive exertion when the pressure in pharynx and trachea is high (FRANKLIN et al. 2002).

During diagnosis, the abnormal breath sounds, rattling and loss of training capability occur. When the soft palate is displaced, slowdown during movement may appear. DDSP episodes cause significant reduction of airflow when breathing out and an increase in the minute ventilation (FRANKLIN et al. 2002). Among horses with DDSP during rest, 76% show intermittent DDSP also during the exertion. However, in most cases, horses that were diagnosed with DDSP would not have any visible symptoms in resting endoscopy. It is a second major case, when the dynamic endoscopy, on a treadmill or overground, is recommended (PARENTE 2018).

Available diagnostic tools

The evaluation of training capacity is based on the changes in the heart rate and the blood-picture. In research conducted in South Africa, in group of horses with abnormal respiratory sounds on larynx and trachea, and decreasing training capacity, pharynx and larynx disorders were observed in 77% of examined horses and in 48%, more than one disorder occurred (MIRAZO et al. 2014). Horses suspected of lowering sports performance due to upper RT disorders were, so far, examined using resting endoscopy. Resting endoscopy performed before and right after the training reveals structural disorders of RT or the diseases that show symptoms in rest, such as mucus inflammation, polyps, cysts, guttural pouches mycosis or permanent dorsal displacement of the soft palate, epiglottis entrapment or inflammations of trachea and presence of exudates (BARAKZAI and DIXON 2011, WOODIE 2011).

Resting endoscopy

Running tests right after the exertion, when the horse is still breathing fast and deep, increases the chance of diagnosing dynamic changes in the pharynx. However it often happens that horses, immediately after the endoscope is inserted, are able to correct the epiglottis position and arytenoid cartilages and vocal folds come back to their resting position which can give false negative results. Another method for diagnosing dynamic disorders of pharynx and larynx is closing the horse's nostrils and stimulating swallowing. It leads to increased pressure in the respiratory tract and imitates exertion. It allows to diagnose epiglottis entrapment and DDSP but the effectiveness of this method is questionable. An application of lobeline was also done to cause hyperventilation and increased the number of breaths in order to simulate to the number reached during exertion. Unfortunately, it was not possible to reach maximum values (FRANKLIN et al. 2008b).

Dynamic endoscopy on the high-speed treadmill

The high-speed treadmill was brought to use which allowed the examination during movement. It gives the opportunity to diagnose changes that can be seen only during the maximum effort. In MELKOVA et al. (2016) research, it was observed that 66% of examined horses had upper RT disorders where 8 of them were diagnosed with DDSP, 4 others with RLH of 2nd, 3th, and 4th degrees. In the same research, it was noted that horses can suffer from more than one upper RT disease and two of the examined horses had simultaneously DDSP and exercise-induced pulmonary hemorrhage.

Other research on the treadmill made it possible to diagnose 71% (LEUTTON and LUMSDEN 2015) and 89% (DORE and KANNEGIETER 1995) of examined horses. DORE and KANNEGIETER (1995) confirmed the diagnosis from resting endoscopy in 19 horses and denied in 21 horses. LEUTTON and LUMSDEN (2015) observed soft palate disorders, vocal folds, and folds of arytenoid cartilages collapse and demonstrated that excessive abduction of arytenoid cartilages may have an influence on the development of additional disorders of pharynx and larynx. On the other hand, TAN et al. (2005), during horses examination on the treadmill, proved that 49% of horses, which showed no symptoms in resting endoscopy, showed changes in dynamic endoscopy. The most common disorder occurring in 105 horses, which is over 50%, was a limping of aryepiglottic folds (TAN et al. 2005). Also, BARAKZAI and DIXON (2011) showed differences between diagnostics in resting and dynamic endoscopy. They examined 281 horses and confirmed DDSP in 47 horses during dynamic endoscopy, while only 25% demonstrated symptoms during resting endoscopy.

Dynamic endoscopy (Figure 1) gave the opportunity for recognizing axial deviation of ery-epiglottic folds (ADAF) during the effort which is caused by the instability of soft palate. It consists in subsiding of membrane part of folds into the larynx, changing its diameter and leading to abnormal sound during inhalation (AHERN and PARENTE 2008). This disorder occurs rarely and is diagnosed even more rarely because of low popularity of dynamic endoscopy. In KING'S et al. (2001) research, in a group of 871 horses, only 52 demonstrated the symptoms of ADAF in dynamic endoscopy.

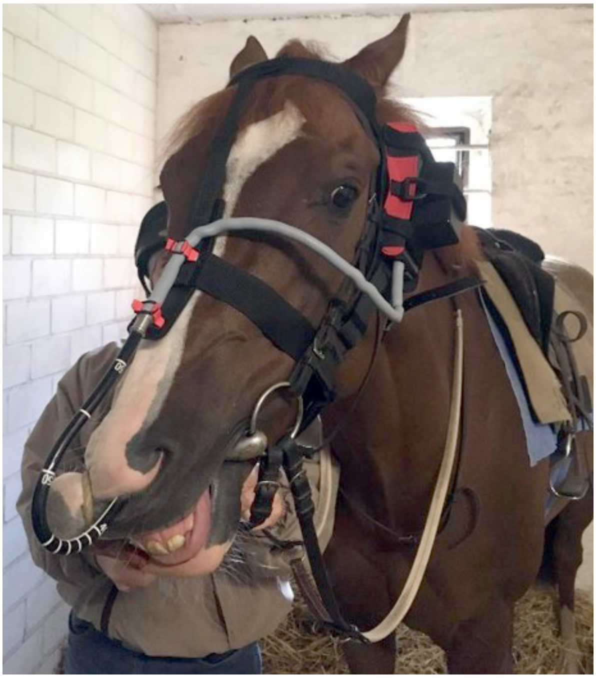

Fig. 1. Head mounted overground laryngoscope

Dynamic overground endoscopy

Dynamic endoscopy on the high-speed treadmill has many advantages according to standardization of examination conditions however, it causes many technical difficulties (MELKOVA et al. 2016). There is a need for a special place, equipment, and staff for operating and controlling. Also, the examination requires the horse to be transported to the clinic, what generates additional costs. It was observed that horses on the treadmill have different length and frequency of steps, presenting different values of exercise capacity parameters compared to standard overground training. Also, the indicators of training capacity such as heart rate and the concentration of lactates were significantly lower after examination on the high-speed treadmill in comparison to overground. Therefore, the treadmill examination doesn't reflect changes during the exertion, especially during natural training with the influence of rider and the neck flexion. STICK and DERKSEN (2010) observed that horses with DDSP often do not show any symptoms on the high-speed treadmill, what can be directly caused by lack of reins tension and different head and neck position. DAVIDSON et al. (2011) proved that the likelihood of diagnosing a dynamic disorder of upper RT increases 3.5 times with the neck flexion during endoscopy examination what is essential especially in dressage horses.

Fig. 2. Overground laryngoscopy examination

The overground endoscopy (Figure 2) is the most technologically advanced examination that allows to adapt the endoscope for in-the-field testing purposes. Mobile endoscopes use the miniaturized endoscopic system, mounted on a special halter. Nowadays, the overground endoscopic systems allow obtaining high-quality video signal almost regardless of the distance from the examined horse to the receiver. In comparison to the first examinations on the lounge, when the horse could not achieve the maximum level of effort (FRANKLIN et al. 2008b, ALLEN and FRANKLIN 2010), a freely moved overground endoscopy allows evaluating the horse in intensive training, essential for symptoms to appear. ELLIOT and CHEETHAM (2018) demonstrated that in the exercise endoscopy, subgrades of LRT are worsening and proportion of complete or partial paralysis is increasing. Overground endoscopy gave the opportunity for examination in everyday, natural environment, during the standard training with harness (HACKETT and LEISE 2018). It was proved that the symptoms of DDSP in race horses can be seen only when the horse is getting close to the finish line (MIRAZO et al. 2014). It allows also to evaluate influence of the rider and the level of head and neck position for the pharynx diameter and airflow (VAN ERCK-WESTERGREN et al. 2013). It is often not possible to diagnose the upper RT disorder during the first dynamic endoscopy because the moment of obstruction may be omitted (ALLEN and FRANKLIN 2010).

Conclusions

Numerous researches prove that overground endoscopy is the best diagnostic method to detect and confirm RLN, DDSP and other dynamic upper RT disorders. It is significant in the aspect of pre-purchase examination, in particular in racehorses in which the frequency of occurring of these disorders is high. Moreover, endoscopy reduced the cost of dynamic upper airway disorders examinations, what is worth attention due to the need to repeat the examination. An overground endoscopy is a valuable tool in the diagnosis of pure performance in show and racing horses.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

AHERN B.J., PARENTE E.J. 2008. S*urgical complications of the equine upper respiratory tract.* Vet. Clin. North Am. Equine Pract., 24(3): 465–484.

ALLEN K.J., LANE J.G., WOODFORD N.S., FRANKLIN S.H. 2007. *Severe collapse of the rostral soft palate as a source of abnormal respiratory noise in six ponies and horses.* Equine Vet. J., 39(6): 562–566.

Allen K.J., Franklin S.H. 2010. *Comparisons of overground endoscopy and treadmill endoscopy in UK Thoroughbred racehorses.* Equine Vet. J., 42(3): 186–191.

Art T., Lekeux P. 2005. *Exercise-induced physiological adjustment to stressfull conditions in sport horses.* Livest. Prod. Sci., 92: 101–111.

Aerts J.M., Gebruers F., Van Camp E., Berckmans D. 2008. *Controlling horse heart rate as a basis for training improvement.* Comput. Electron. Agric., 64(1): 78–84.

Barakzai S.Z., Dixon P.M. 2011. *Correlation of resting and exercising endoscopic findings for horses with dynamic laryngeal collapse and palatal dysfunction.* Equine Vet. J., (1): 18–23.

Burlikowska K., Bogusławska-Tryk M., Szymeczko R., Piotrowska A. 2015. *Hematologiczne i biochemiczne parametry krwi koni użytkowanych sportowo i rekreacyjnie.* JCEA, 16(4): 370–382.

Butler P.J., Woakes A.J., Smale K., Roberts C.A., Hillidge C.J., Snow D.H., Marlin D.J. 1993. *Respiratory and cardiovascular adjustments during exercise of increasing intensity and during recovery in thoroughbred racehorses.* J. Exp. Biol., 179:159–180.

Collins N., Milne E.C., Dixon P. 2009. *Correlation of the Havemeyer endoscopic laryngeal grading system with histopathological changes in equine cricoarytenoideus dorsalis muscles.* Ir Vet. J., 62(5): 334–338.

Dart A., Dowling B., Smith C. 2005. *Upper airway dysfunction associated with collapse of the apex of the corniculate process of the left arytenoid cartilage during exercise in 15 horses.* Vet. Surg., 34: 543–547.

Davidson E.J., Martin B.B., Boston R.C., Parente E.J. 2011. *Exercising upper respiratory videoendoscopic evaluation of 100 nonracing performance horses with abnormal respiratory noise and/or poor performance.* Equine Vet. J., 43(1): 3–8.

Dixon P.M., Mcgorum B.C., Railton D.I., Hawe C., Tremaine W.H., Pickles K., Mccann J. 2001. *Laryngeal paralysis: a study of 375 cases in a mixed-breed population of horses.* Equine Vet. J., 33(5): 452–458.

Dore M.L., Kannegieter N.J. 1995. *Endoscopy of the upper respiratory tract during treadmill exercise: a clinical study of 100 horses.* Aust. Vet. J., 72(3): 101–107.

Ducharme N.G., Hackett R.P., Ainsworth D.A., Shannon K. 1994. *Measurement of upper respiratory pressures in exercising horses-repeatability and normal values.* Am. J. Vet. Res., 55: 368–374.

Ducharme N.G., Hackett R.P., Gleed R.D., Aainsworth D.M., Erb H.N., Mitchell L.M. Soderholm L.V. 1999. *Pulmonary capillary pressure in horses undergoing alteration of pleural pressure by imposition of various upper airway resistive loads.* Equine Vet. J. Suppl., 30: 21–33.

Dupuis M., Zhang Z., Durkin K., Charlier C., Lekeux P., Georges M. 2012. *Detection of copy number variants in the horse genome and examination of their association with recurrent laryngeal neuropathy.* Anim. Genet., 44: 206–208.

Durando M.M., Martin B.B., Hammer E.J., Langsam S.P., Birks E.K. 2002. *Dynamic upper airway changes and arterial blood gasparameters during treadmill exercise.* Equine Vet. J. Suppl., 34: 408–412.

Elliott S., Cheetham J. *2018. Meta-analysis evaluating resting laryngeal endoscopy as a diagnostic tool for recurrent laryngeal neuropathy in the equine athlete.* Equine Vet. J., 51(2): 167–172.

Franklin S.H. 2008a. *Dynamic collapse of the upper respiratory tract: A review.* Equine Vet. Educ., 20(4): 212–224.

Franklin S.H., Burn J.F., Allen KJ. 2008b. *Clinical trials using a telemetric endoscope for use during over-ground exercise: A preliminary study.* Equine Vet. J., 40(7): 712–715.

Franklin S.H., Naylor J.R.J., Lane J.G. 2002. *Effect of dorsal displacement of the soft palate on ventilation and airflow during high-intensity exercise.* Equine Vet. J. Suppl., 34: 379–383.

Franklin S.H., Usmar S.G., Lane J.G., Shuttleworth J. Burn J.F. 2003. *Spectral analysis of respiratory noise in horses with upper airway disorders.* Equine Vet. J., 35(3): 264–268.

GARRETT K.S., WOODIE J.B., EMBERTSON R.M., PEASE A.P. 2009. *Diagnosis of laryngeal dysplasia in five horses using magnetic resonance imaging and ultrasonography*. Equine Vet. J., 41(8): 766–771.

HACKETT E.S., LEISE B.S. 2019. *Exercising upper respiratory videoendoscopic findings of 50 competition draught horses with abnormal respiratory noise and/or poor performance*. Equine Vet. J., 51(3): 370–374.

KING D.S., TULLENERS E., MARTIN B.B., PARENTE E.J., BOSTON R. 2001. C*linical experiences with axial deviation of the aryepiglottic folds in 52 racehorses*. Vet. Surg., 30: 151–160.

LEUTTON J.L., LUMSDEN J.M. 2015. *Dynamic respiratory endoscopic findings pre- and post laryngoplasty in thoroughbred racehorses*. Equine Vet., J. 47(5): 531–536.

MELKOVA P., JAHN P., BODECEK S., DOBESOVA O., HANAK J. 2016. *Evaluation of poor performance in racehorses using a high-speed treadmill*. Vet. Med., 61(5): 243–248.

MIRAZO J.E., PAGE P., RUBIO-MARTINEZ L., MARAIS H.J., LYLE C. 2014. *Dynamic upper respiratory abnormalities in Thoroughbred racehorses in South Africa*. J. S. Afr. Vet. Assoc., 85(1): 1140.

PARENTE E.J. 2018. *Upper Airway Conditions Affecting the Equine Athlete*. Vet. Clin. North Am. Equine Pract., 34(2): 427–441.

RHEE H.S., STEEL C.M., DERKSEN F.J., ROBINSON N.E., HOH J.F.Y. 2009. *Immunohistochemical analysis of laryngeal muscles in normal horses and horses with subclinical recurrent laryngeal neuropathy*. J. Histochem. Cytochem., 57(8): 787–800.

SANCHEZ A., COUETIL L.L., WARD M.P., CLARK S.P. 2005. *Effect of airway disease on blood gas exchange in racehorses*. J. Vet. Intern. Med., 19: 87–92.

STICK J., DERKSEN F. 2010. *The impact of technology on the study of equine upper airway surgery*. Pferdeheilkunde, 26(4): 523–530.

TAN R.H., DOWLING B.A., DART A.J. 2005. *High-speed treadmill videoendoscopic examination of the upper respiratory tract in the horse: the results of 291 clinical cases*. Vet. J., 170(2): 243–248.

WOODIE J.B. 2011. *Evaluation of the upper respiratory tract at rest and during exercise*. AAEP Proceedings, 57: 1–4.

VAN ERCK-WESTERGREN E., FRANKLIN S.H., BAYLY W.M. 2013. *Respiratory diseases and their effects on respiratory function and exercise capacity*. Equine Vet., J. 45: 376–387.