Effect of a tongue-tie on upper airway mechanics during exercise following sternothyrohyoid myectomy in clinically normal horses

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Objective—To determine the effect of a tongue-tie on upper airway mechanics in clinically normal horses exercising on a treadmill following sternothyrohyoid myectomy.

Animals—6 Standardbreds.

Procedure—Upper airway mechanics were measured with horses exercising on a treadmill at 5, 8, and 10 m/s 4 weeks after a sternothyrohyoid myectomy was performed. Pharyngeal and tracheal inspiratory and expiratory pressures were measured by use of transnasal pharyngeal and tracheal catheters connected to differential pressure transducers. Horses were fitted with a facemask and airflow was measured by use of a pneumotachograph. Horses underwent a standardized exercise protocol on a treadmill at 5, 8, and 10 m/s with and without a tongue-tie in a randomized cross-over design. Inspiratory and expiratory airflow, tracheal pressure, and pharyngeal pressure were measured, and inspiratory and expiratory resistances were calculated.

Results—We were unable to detect an effect of a tongue-tie on any of the respiratory variables measured.

Conclusions and Clinical Relevance—Results indicate that a tongue-tie does not alter upper airway mechanics following sternothyrohyoid myectomy in clinically normal horses during exercise. (*Am J Vet Res* 2001;62:779–782)

Dorsal displacement of the soft palate (DDSP) is a common performance-limiting condition in racehorses. The pathogenesis is unclear and may be multifactorial.[1] Caudal displacement of the larynx is believed to predispose horses to DDSP. Caudal retraction of the tongue may allow the larynx to be displaced caudally, disrupting the laryngopalatal articulation and, therefore, predisposing a horse to DDSP. Also, the base of the retracted tongue may physically displace the palate dorsally.[1] A tongue-tie is commonly recommended as the initial treatment and as an adjunct to other medical and surgical treatments for DDSP.[2-5]

Upper airway patency is the result of complex interactions of multiple pairs of opposing muscles that tense the palate, pull the hyoid bone ventrally, pull the tongue forward, and dilate the nasopharynx.[6] The rostral pull of the genioglossus and geniohyoid muscles are opposed by caudal traction of the sternothyroideus and sternohyoideus muscles. These opposing muscles pull the hyoid apparatus ventrally and dilate the nasopharynx, enabling it to resist dynamic collapse.[6-14] The tongue, genioglossus, and hyoglossus muscles have the ability to alter the position of the hyoid bone and affect laryngopalatal relationships.

Continued use of a tongue-tie following sternothyrohyoid myectomy is commonly recommended, hence the desirability of knowing the contribution of the tongue-tie. The effect of a sternothyrohyoid myectomy on airway mechanics has been reported[15]; however, to our knowledge, the effects of a tongue-tie have not been examined. The purpose of the study reported here was to measure the effect of rostral traction of the tongue by a tongue-tie on upper airway mechanics following sternothyrohyoid myectomy in clinically normal horses during exercise.

Materials and Methods

Horses—Six Standardbred horses were used; 3 males (castrated) and 3 females. Horses were 2 to 7 years old and weighed 440 to 510 kg. All horses received paddock exercise for 2 weeks before initiation of the study and were maintained on mixed hay free-choice and water. Horses were housed individually in box stalls during the study. All horses were vaccinated against equine influenza virus, equine viral rhinopneumonitis, eastern and western equine encephalitis, and *Streptococcus equi*. Physical examinations of the horses and endoscopic examinations of the larynx and pharynx revealed no abnormalities. Horses had sternothyrohyoid myectomies performed 4 weeks prior to this study, using a previously described technique.[16] Horses were trained for 10 weeks on the treadmill prior to the experiment to familiarize the horses to the equipment used in the study and to maintain a consistent level of fitness among the group. Incremental exercise tests were performed on each horse to determine the speed that induced maximal oxygen consumption.[17]

Instrumentation—Horses were instrumented while on the treadmill to obtain dynamic measurements of upper airway function. Inspiratory and expiratory tracheal and pharyngeal pressure and inspiratory and expiratory flows were measured. Transnasal pharyngeal and tracheal catheters were passed through the left nares and secured to the muzzle with adhesive tape.[15]

The pharyngeal catheter was positioned at the level of the left guttural pouch opening, and the tracheal catheter was positioned at the junction of the proximal and middle thirds of the cervical trachea. Catheters were 176 cm in length and constructed of teflon[a] (internal diameter, 2.38 mm; outer

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diameter, 3.97 mm).[18] Each catheter had 4 side holes beginning a distance of 8 catheter diameters from the sealed tip. Catheters were phase matched at 5, 10, and 15 Hz.[19] Tracheal and pharyngeal pressures were measured by use of differential pressure transducers,[b] and pressures were recorded on a physiograph.[c] The differential pressure transducers were calibrated by use of a water manometer before and after each experiment. An airtight face mask was constructed from injection-molded plastic and was formfitted to the horse's head with insulation foam. The catheters exited the caudal aspect of the mask. Airflow was measured by use of a 15 cm pneumotachograph[d] mounted on the face mask.

Inspiratory and expiratory flows were determined by measuring air pressure changes across the pneumotachograph. A differential pressure transducer was used to measure the change in pressure across the pneumotachograph, which was proportional to flow. The signal was recorded on a physiologic recorder. The combined resistance of the pneumotachograph facemask system was 0.043 cm H_2O/L/s at 70 L/s. The pneumotachograph was calibrated prior to each study by forcing known airflows through the face mask system and measuring airflows with a rotameter flowmeter[e] capable of measuring airflow up to 90 L/s. Inspiratory and expiratory tracheal and pharyngeal pressures and inspiratory and expiratory flow were obtained from the physiograph tracing.

Tongue-tie procedure—A tongue-tie was applied by pulling the tongue out of the mouth as far rostrally as possible. Subsequently, at the level of the frenulum, the tongue was tied to the horizontal ramus of the mandible with a piece of cotton cloth.

Exercise protocol—Horses were exercised on a 0 degree incline treadmill for 5 minutes before the experiment began; horses walked for 1 minute (2 m/s), trotted for 2 minutes (5 m/s), and cantered for 2 minutes (10 m/s). Horses were instrumented with transnasal pharyngeal and tracheal catheters and the airtight face mask. Horses were exercised on the treadmill at 5, 8, and 10 m/s for 120 seconds at each speed. These speeds approximated the speeds that induced 50, 75, and 100% of maximal oxygen consumption. Measurements were obtained during the last 60 seconds of exercise at each speed. Catheters were flushed with air at 20 psi to clear the catheters of any exudate every 60 seconds. The pneumotachograph was dried with pressurized air between horses to remove any particulate material or condensation that may have accumulated during the experiment. Each horse was exercised on consecutive days in a randomized cross-over design with and without a tongue-tie.

Data analyses—Peak tracheal and pharyngeal pressures and airflows were measured on the physiograph tracing. Peak tracheal and pharyngeal pressures and airflow were calculated as the mean of 10 consecutive breaths for each horse at each speed to determine a data point. We defined **pharyngeal resistance (R_P)** as (P atmosphere – P pharynx) / peak airflow. **Tracheal resistance (R_{TR})** was defined as (P atmosphere – P tracheal) / peak airflow. Inspiratory and expiratory pharyngeal and tracheal resistances were calculated as the ratio of peak pressure to peak airflow for each breath.[15,20] Data were analyzed by use of 2-way repeated-measures ANOVA. Pairwise comparisons were evaluated by use of the Student Newman-Keul test. Values of $P < 0.05$ were considered significant. Statistical power was calculated for the ability to detect a 25% difference (2-tailed) between treatments on the 10 m/s data for all variables.

Results

We were unable to detect an effect of a tongue-tie on any of the variables measured. Interaction between treadmill speed and treatment was not observed (**Table 1**). Tracheal and pharyngeal inspiratory and expiratory peak airway pressures increased significantly with increasing speed, as did inspiratory and expiratory airflow. Tracheal and pharyngeal inspiratory resistance increased significantly with increasing speed, whereas expiratory resistance was unaffected by speed.

Table 1—Measurements of airway variables in horses running on a treadmill with (TT) and without (NTT) a tongue-tie. All values are expressed as mean ± SEM

Variable	TT/NTT	Speed		
		5 m/s	8 m/s	10 m/s
P_{TRIN}	NTT	16.4 ± 2.4	25.2 ± 2.4*	32.1 ± .5*†
(cm H_2O)	TT	14.1 ± 0.8	23.8 ± 1.7*	31.5 ± .0*†
P_{TREX}	NTT	10.2 ± 1.1	13.7 ± 1.8	16.7 ± 3.1*
(cm H_2O)	TT	10.8 ± 1.1	13.6 ± 2.1	15.7 ± 3.1*
P_{PIN}	NTT	8.6 ± 0.7	12.0 ± 1.0*	15.5 ± .5*†
(cm H_2O)	TT	7.6 ± 0.6	12.3 ± 1.1*	16.0 ± .7*†
P_{PEX}	NTT	7.6 ± 0.8	9.8 ± 0.9	12.7 ± 2.6*
(cm H_2O)	TT	7.4 ± 0.7	10.7 ± 1.4	13.5 ± 1.8*
$Flow_{IN}$	NTT	30.6 ± 3.1	41.9 ± 1.2*	51.3 ± 1.0*†
(L/s)	TT	34.0 ± 4.0	44.1 ± 1.6*	52.6 ± 2.5*†
$Flow_{EX}$	NTT	42.4 ± 5.4	57.0 ± 3.3*	66.5± 3.9*†
(L/s)	TT	42.3 ± 5.2	60.1 ± 7.1*	64.5 ± 5.9*†
R_{TRIN}	NTT	0.53 ± 0.04	0.60 ± 0 .05*	0.63 ± 0.05*†
(cm H_2O/L/s)	TT	0.44 ± .05	0.54 ± .05*	0.61 ± 0.05*†
R_{TREX}	NTT	0.26 ± .04	0.25 ± .05	0.26 ± 0.05
(cm H_2O/L/s)	TT	0.27 ± .03	0.23 ± .03	0.25 ± 0.05
R_{PIN}	NTT	0.29 ± .03	0.29 ± .02	0.31 ± 0.03*
(cm H_2O/L/s)	TT	0.23 ± .02	0.28 ± .03	0.31 ± 0.03*
R_{PEX}	NTT	0.20 ± .03	0.18 ± .02	0.20 ± 0.05
(cm H_2O/L/s)	TT	0.19 ± .03	0.18 ± .01	0.21 ± 0.03

*Significantly ($P < 0.05$) different from 5 m/s value. †Significantly ($P < 0.05$) different from 8 m/s value.

P_{TRIN} = Peak tracheal inspiratory pressure. P_{TREX} = Peak tracheal expiratory pressure. P_{PIN} = Peak pharyngeal inspiratory pressure. P_{PEX} = Peak pharyngeal expiratory pressure. $Flow_{IN}$ = Peak inspiratory flow. $Flow_{EX}$ = Peak expiratory flow. R_{TRIN} = Peak tracheal inspiratory resistance. R_{TREX} = Peak tracheal expiratory resistance. R_{PIN} = Peak pharyngeal inspiratory resistance. R_{PEX} = Peak pharyngeal expiratory resistance.

Discussion

We investigated the effect of rostral traction of the tongue with a tongue-tie on upper airway mechanics following sternothyrohyoid myectomy in clinically normal horses during exercise. Use of a tongue-tie did not affect upper airway mechanics, which confirmed our clinical experience that use of a tongue-tie does not cause any detrimental effects on respiratory function. Likewise, we were unable to demonstrate, on the basis of airway mechanics, an explanation for the empirically observed benefit of tongue-ties. Lack of demonstrable effects on airway function must be interpreted in light of the fact that these were clinically normal horses. It is probable that the tongue-tie does not alter airway mechanics per se; it prevents the palate from displacing, by an as yet unidentified mechanism, and subsequently precludes the development of abnormal airway mechanics. Results of a clinical study of airway mechanics in horses known to develop DDSP have revealed that changes in airway mechanics are usually demonstrable only after DDSP occurs.[f]

Upper airway patency is a complex interaction of opposing muscle groups that cause dilatation of the nasopharynx and tense the palate to resist dynamic collapse. The role of these muscles as pharyngeal dilators has been demonstrated in cats, dogs, and rabbits.[6,10,11,21,22] These muscles have maximal electrical activity during inspiration and increase pharyngeal stability; the negative pressure required to cause airway collapse during stimulation of these muscles increases.[6,12] It is believed that rostral traction of the tongue augments the pharyngeal dilator effect of the sternothyroideus and sternohyoideus muscles.

The tongue, through its attachments, influences airway conformation and function in many ways. The tongue attaches to the hyoid bone via the hyoglossus muscle, which serves to pull the hyoid bone rostrally. The glossoepiglottic fold serves as an attachment from the base of the tongue to the ventral border of the epiglottis. These attachments form the empirical basis for the use of a tongue-tie.

There is abundant evidence in other species that the tongue, genioglossus, and geniohyoid play a considerable role in airway enlargement. Posterior displacement of the tongue can occlude the airway.[14] This is, in part, the rationale for the common usage of a tongue-tie. Contraction of the genioglossus displaces the hyoid bone ventrally and enlarges the airway, thereby decreasing resistance in dogs, cats, and rabbits.[6,10,11,22] Similarly, electrical stimulation of the genioglossus decreases upper airway resistance.[8] Furthermore, pharyngeal resistance remains constant during increased negative inspiratory pressure because of increased genioglossus activity.[7] Electrical activity of the geniohyoid muscle precedes inspiratory flow and relaxation of the genioglossus is the main impediment to upper airway flow.[9,14]

In our study, the phase relationship between pressure and flow was not altered by a tongue-tie. Because inertia and airway deformation result in complex upper airway pressure and flow relationships at high respiratory flow rates, pressure and flow signals generated during exercise were not in phase (ie, have the same wave form but do not occur at the same time).[23] Therefore, inspiratory and expiratory pressure and peak inspiratory and expiratory flow rates were measured for a given breath. Inspiratory and expiratory resistance were calculated from the ratio of peak pressure and flow measurements over 10 breaths. Complex impedance is the ratio of the pressure to the flow at a given frequency. Complex impedance may be thought of as a generalization of resistance, but whereas resistance describes only resistive (frictional) induced pressure differences, impedance describes pressure differences across resistive, elastic, or inertial elements.[23]

There are a number of possible explanations for our inability to demonstrate an effect of a tongue-tie on upper airway mechanics. Geniohyoid and genioglossus muscle activity may have been maximal in the horses of this study, and rostral displacement of the tongue may not have further augmented pharyngeal dilator function. Furthermore, traction on the tongue is not equivalent to muscle contraction and may only serve to passively stretch these muscles. Beneficial effects of a tongue-tie in altering airway geometry and minimizing the effect of dynamic collapse should be most pronounced when horses are running at higher speeds. Power calculations for the ability to detect a 25% change on the data obtained at 10 m/s ranged from 0.73 to 1.0.

The effect of a sternothyrohyoid myectomy on our findings was not determined. Continued use of a tongue-tie following myectomy is recommended; therefore, the use of horses that have undergone sternothyrohyoid myectomy is appropriate for investigation of the effect of a tongue-tie. This study was performed 30 days following myectomy. A randomized cross-over experimental design with trials run on consecutive days ensured that the only variable altered was the use of a tongue-tie.

Results of our study do not detract from the possible efficacy of a tongue-tie. Racing conditions differ from the experimental setting in that head position can be altered with horses under harness, whereas horses in our study were allowed to run with the head unencumbered. Although not actively causing contraction, the tongue-tie likely prevents caudal displacement of the base of the tongue. It is conceivable that an altered head position may displace the base of the tongue caudally and dorsally such that contraction of the geniohyoid may be ineffectual in stabilizing the pharyngeal musculature to prevent collapse and displacement. It is possible that the benefit of a tongue-tie may only be demonstrable in horses with DDSP.

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[a]FEP teflon tubing, A Daiger Scientific Division, Wheeling, Ill.
[b]DP-45, Validyne Engineering Sales Corp, Northridge, Calif.
[c]VR 12 Physiologic Monitoring Systems, PPG Biomedical Systems, Bensalem, Pa.
[d]TZ-7 Laminar flow element, Meriam Instrument Co, Cleveland, Ohio.
[e]Full View Flow Meter Model FV110C, Brooks Instrument Division, Hatfield, Pa.
[f]Redher R, Ducharme NG, Hackett RP, et al. Simultaneous videoendoscopy and measurement of airway pressures in exercising horses with dorsal displacement of the soft palate (abstr). *Vet Surg* 1991;20:344.

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