# Effect of a tongue-tie on upper airway mechanics in horses during exercise

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**Objective**—To determine the effect of a tongue-tie on upper airway mechanics in exercising horses.

**Animals**—5 Standardbreds.

**Procedure**—Peak inspiratory and expiratory tracheal and pharyngeal pressures and airflow were measured while horses exercised on a treadmill with and without a tongue-tie. Respiratory rate was also measured. Horses ran at speeds that corresponded to 50 ($HR_{50}$), 75, 90 ($HR_{90}$), and 100% of maximal heart rate. The tongue-tie was applied by pulling the tongue forward out of the mouth as far as possible and tying it at the level of the base of the frenulum to the mandible with an elastic gauze bandage. Peak inspiratory and expiratory tracheal, pharyngeal, and translaryngeal resistance, minute ventilation, and tidal volume were calculated. Data were analyzed by use of 2-way repeated-measures ANOVA. For post hoc comparison of significant data, the Student-Newman-Keuls test was used.

**Results**—We were unable to detect significant differences between groups for peak inspiratory or expiratory tracheal or pharyngeal resistance, peak pressure, peak expiratory flow, tidal volume, respiratory rate, or minute ventilation. Horses that ran with a tongue-tie had significantly higher peak inspiratory flows, compared with horses that ran without a tongue-tie. In the post hoc comparison, this effect was significant at 4 m/s, $HR_{50}$, and $HR_{90}$.

**Conclusion and Clinical Relevance**—Application of a tongue-tie did not alter upper respiratory mechanics in exercising horses and may be beneficial in exercising horses with certain types of obstructive dysfunction of the upper airways. However, application of a tongue-tie does not improve upper airway mechanics in clinically normal horses. (*Am J Vet Res* 2001; 62:775-778)

Many racehorses with poor racing performance run with their tongues tied in an attempt to improve airway function of the upper portion of the respiratory tract (upper airways). Historically, reported use of a tongue-tie dates as far back as 1889 when it was recommended "to tie the tongue to the floor of the mouth to get rid of annoying respiratory noise during exercise."[1] However, although today's application of a tongue-tie still focuses on respiratory noise in conjunction with poor performance, many horses are run with their tongues tied to improve racing performance. Oftentimes, the cause of poor performance is not diagnosed in these horses. This broad and ill-defined application of the tongue-tie in racehorses makes it difficult to determine whether tying the tongue affects performance and upper airway function. To the authors' knowledge, there are no objective scientific data regarding the influence of a tongue-tie on performance or upper airway function in horses.

Studies in other species have revealed that activity of extrinsic tongue muscles, especially the genioglossus muscle, may be important in stability and patency of the upper airways.[2-9] The genioglossus muscle is an extrinsic tongue muscle that is responsible for tongue protrusion.[10] On the basis of comparative literature regarding function of the genioglossus muscle, we hypothesized that horses running with their tongues tied would have improved function of the upper airways. Therefore, the purpose of the study reported here was to determine upper airway function in exercising horses with and without a tongue-tie.

## Materials and Methods

**Horses**—Five Standardbred horses were used; 4 geldings and 1 mare. Horses were 5 to 11 years old and weighed 486 to 527 kg. The study was approved by the All University Committee for Animal Use and Care. Horses were maintained on pasture and vaccinated against tetanus, equine influenza virus, equine viral rhinopneumonitis, eastern and western equine encephalomyelitis, and *Streptococcus equi*. Physical examination of the horses, as well endoscopic examination of the upper portion of the respiratory tract at rest and while exercising on a treadmill revealed no abnormalities. Prior to the experiments, the horses were trained to run on the treadmill. Speeds corresponding to **maximal heart rate ($HR_{MAX}$)** for each horse were determined during an incremental exercise test, and heart rate was determined by use of a telemetric electrocardiography system.[a] The speeds corresponding to **50% of maximal heart rate ($HR_{50}$), 75% of maximal heart rate, ($HR_{75}$), and 90% of maximal heart rate ($HR_{90}$)** were subsequently interpolated from these data.[11]

**Instrumentation**—One hundred and fifty centimeter long polyethylene (polyethylene tubing, 2.15 mm internal diameter; 3.25 outside diameter) sidehole catheters[b] were used to measure tracheal and nasopharyngeal pressures. Tracheal and pharyngeal pressures were measured by use of differential pressure transducers[c] and recorded on a respiratory function computer. Transducers were calibrated before each experiment with a water manometer. Airflow was measured with a 15.2-cm diameter pneumotachograph,[d] which was fitted on a fiberglass facemask. The resistance of the pneumotachograph was 0.04 cm $H_2O$/L/s at 90 L/s, whereas the combined resistance of the face mask plus the pneumotachograph was 0.05 cm $H_2O$/L/s at 90/L/s. Before each experiment, the pneumotachograph was calibrated with a rotameter[e] capable of measuring flows up to 90 L/s.

**Tongue-tie procedure**—A tongue-tie was applied by

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Table 1—Measurements of respiratory function in horses running on a treadmill with (TT) or without (NTT) a tongue-tie (mean ± SD)

| | | SPEED | | | | |
|---|---|---|---|---|---|---|
| | NTT/TT | 4 M/S | $HR_{50}$ | $HR_{75}$ | $HR_{90}$ | $HR_{max}$ |
| $FLOW_{IN}$ | NTT | 34.3 ± 6.8 | 39.1 ± 7.5 | 51.7 ± 6.3 | 58.9 ± 3.5 | 62.7 ± 5.8 |
| | TT | 38.8 ± 6.4* | 44.6 ± 9.3* | 55.0 ± 7.0 | 63.4 ± 4.6* | 64.9 ± 4.0 |
| $FLOW_{EX}$ | NTT | 28.9 ± 3.6 | 37.5 ± 6.1 | 45.9 ± 3.9 | 50.2 ± 3.8 | 54.4 ± 1.9 |
| | TT | 34.6 ± 4.9 | 42.0 ± 4.4 | 49.0 ± 4.0 | 54.7 ± 3.9 | 55.1 ± 3.4 |
| $VT_I$ | NTT | 9.8 ± 1.7 | 12.0 ± 1.5 | 15.6 ± 2.2 | 16.6 ± 1.8 | 17.6 ± 1.1 |
| | TT | 9.7 ± 1.2 | 12.0 ± 1.4 | 16.0 ± 2.5 | 18.2 ± 2.8 | 19.6 ± 3.8 |
| $F_{RESP}$ | NTT | 79.3 ± 22.4 | 77.1 ± 16.1 | 73.5 ± .8 | 1.8 ± 10.6 | 83.1 ± 9.8 |
| | TT | 90.6 ± 11.4 | 85.6 ± 11.5 | 82.2 ± 7.6 | 85.0 ± 7.6 | 82.0 ± 14.0 |
| $VENT_{MIN}$ | NTT | 896 ± 240 | 1038 ± 46 | 1284 ± 229 | 1420 ± 232 | 1444 ± 240 |
| | TT | 786 ± 287 | 934 ± 244 | 1198 ± 63 | 1496 ± 353 | 1624 ± 359 |
| $P_{TRIN}$ | NTT | 14.0 ± 3.1 | 16.8 ± 3.8 | 25.9 ± 7.6 | 30.8 ± 5.6 | 33.6 ± 5.9 |
| | TT | 14.4 ± 2.7 | 18.9 ± 6.1 | 25.7 ± 7.0 | 33.4 ± 5.0 | 36.3 ± 5.5 |
| $P_{TREX}$ | NTT | 7.4 ± 1.1 | 9.2 ± 0.7 | 11.4 ± 1.3 | 12.0 ± 1.0 | 12.8 ± 1.6 |
| | TT | 7.5 ± 1.0 | 10.3 ± 2.3 | 12.4 ± 2.7 | 12.7 ± 2.1 | 13.3 ± 2.0 |
| $R_{TRIN}$ | NTT | 0.41 ± 0.12 | 0.44 ± 0.11 | 0.51 ± 0.16 | 0.53 ± .11 | 0.54 ± .11 |
| | TT | 0.37 ± 0.07 | 0.43 ± 0.13 | 0.47 ± 0.14 | 0.53 ± .11 | 0.56 ± .10 |
| $R_{TREX}$ | NTT | 0.24 ± 0.06 | 0.25 ± 0.04 | 0.25 ± 0.04 | 0.24 ± .02 | 0.24 ± 0.04 |
| | TT | 0.22 ± 0.04 | 0.25 ± 0.06 | 0.26 ± 0.06 | 0.23 ± .03 | 0.24 ± 0.04 |
| $P_{PHIN}$ | NTT | 11.7 ± 3.0 | 13.9 ± 4.0 | 19.8 ± 4.7 | 21.7 ± 4.9 | 23.3 ± 6.9 |
| | TT | 11.6 ± 3.2 | 13.7 ± 3.0 | 18.7 ± 4.4 | 21.5 ± 6.2 | 22.8 ± 6.8 |
| $P_{PHEX}$ | NTT | 4.6 ± 0.8 | 6.2 ± 0.8 | 8.2 ± 1.7 | 8.1 ± 1.2 | 9.2 ± 1.9 |
| | TT | 5.4 ± 1.7 | 6.8 ± 1.1 | 8.3 ± 1.8 | 9.4 ± 2.1 | 9.6 ± 2.8 |
| $R_{PHIN}$ | NTT | 0.34 ± 0.09 | 0.35 ± 0.09 | 0.39 ± .10 | 0.37 ± 0.08 | 0.37 ± 0.09 |
| | TT | 0.30 ± 0.07 | 0.31 ± 0.06 | 0.34 ± 0.07 | 0.34 ± 0.09 | 0.35 ± 0.10 |
| $R_{PHEX}$ | NTT | 0.16 ± 0.06 | 0.17 ± 0.05 | 0.18 ± 0.05 | 0.16 ± 0.03 | 0.17 ± 0.04 |
| | TT | 0.15 ± 0.03 | 0.16 ± 0.03 | 0.17 ± 0.03 | 0.17 ± 0.04 | 0.17 ± 0.04 |
| $R_{TRLARIN}$ | NTT | 0.07 ± 0.10 | 0.08 ± 0.09 | 0.12 ± 0.10 | 0.16 ± 0.12 | 0.17 ± 0.11 |
| | TT | 0.07 ± 0.10 | 0.12 ± 0.11 | 0.13 ± 0.13 | 0.19 ± 0.15 | 0.21 ± 0.15 |
| $R_{TRLAREX}$ | NTT | 0.10 ± 0.04 | 0.08 ± 0.02 | 0.07 ± 0.01 | 0.08 ± 0.01 | 0.07 ± 0.01 |
| | TT | 0.07 ± 0.06 | 0.08 ± 0.07 | 0.09 ± 0.06 | 0.06 ± 0.03 | 0.07 ± 0.06 |

*Indicates significant ($P < 0.05$) differences were detected.

$Flow_{in}$ = Peak inspiratory flow (L/s). $Flow_{ex}$ = Peak expiratory flow (L/s). VT = Tidal volume (L). $F_{RESP}$ = Respiratory frequency (breaths/min). $VENT_{MIN}$ = Minute ventilation (L). $P_{TREX}$ = Peak tracheal expiratory pressure (cm $H_2O$). $P_{TRIN}$ = Peak tracheal inspiratory pressure (cm $H_2O$). $R_{TRIN}$ = Peak tracheal inspiratory resistance (cm $H_2O$/L/s). $R_{TREX}$ = Peak tracheal expiratory resistance (cm $H_2O$/L/s). $P_{PEX}$ = Peak pharyngeal expiratory pressure (cm $H_2O$). $P_{PIN}$ = Peak pharyngeal inspiratory pressure (cm $H_2O$), $R_{PIN}$ = Peak pharyngeal inspiratory resistance (cm $H_2O$/L/s). $R_{PEX}$ = Peak pharyngeal expiratory resistance (cm $H_2O$/L/s). $R_{TRLARIN}$ = Peak translaryngeal inspiratory resistance (cm $H_2O$/L/s). $R_{TRLAREX}$ = Peak translaryngeal expiratory resistance (cm $H_2O$/L/s). 4 M/S = 4 meters per second. $HR_{50}$ = 50% of maximum heart rate. $HR_{75}$ = 75% of maximum heart rate. $HR_{90}$ = 90% maximum heart rate. $HR_{max}$ = Maximum heart rate.

pulling the tongue out of the mouth as far as possible. Subsequently, at the level of the base of the frenulum, the tongue was tied to the mandible with an elastic gauze bandage. Catheters for tracheal and pharyngeal pressures were passed through the right naris and under endoscopic guidance. The tracheal catheter was positioned at the level of the upper proximal third of the cervical portion of the trachea, and the nasopharyngeal catheter was positioned at the level of the opening of the right guttural pouch. The face mask was fitted on each horse's head with a rubber shroud and adhesive to ensure that the face mask was airtight. The pneumotachograph was then attached to the mask.

**Experimental design**—Horses were run on a high-speed treadmill with or without a tongue-tie in a randomized crossover design. There were 2 to 4 days between trials. Horses warmed-up on the treadmill at 4 m/s for 3 minutes and then ran at speeds that corresponded to $HR_{50}$, $HR_{75}$, $HR_{90}$, and $HR_{MAX}$ for 60 seconds at each speed. Pressures and airflow measurements were collected on the respiratory function computer.

**Data analyses**—The mean of 10 consecutive breaths was calculated for peak inspiratory and expiratory tracheal and pharyngeal pressures and airflows at each speed. Peak inspiratory and expiratory tracheal and pharyngeal resistance was calculated as peak pressure divided by peak airflow. The difference between peak tracheal pressure and peak pharyngeal pressure during inspiration or expiration divided by the corresponding peak flow was calculated to determine the translaryngeal inspiratory and expiratory resistance. Tidal volume was determined by measuring the area under the inspiratory flow curve.[f] Respiratory rate was determined by counting the number of breaths during the last 30 seconds at each speed. Minute ventilation was calculated as tidal volume × respiratory rate per minute.

Data were analyzed by 2-way repeated-measures ANOVA. For post hoc pairwise comparison of significant data, the Student-Newman-Keul test was used. Values of $P < 0.05$ were considered significant.

## Results

Peak inspiratory flow was significantly ($P < 0.009$) higher in horses exercising with a tongue-tie than those without a tongue-tie. In the post hoc comparison, this was significant at the speeds 4 m/s, $HR_{50}$, and $HR_{90}$ (**Table 1**). Significant differences were not detected in any of the other variables measured or calculated for horses running with or without a tongue-tie.

## Discussion

In this study, we were unable to measure any significant effect of a tongue-tie on upper airway function in exercising horses. There was a significant increase in peak inspiratory flow in horses with a tongue-tie, compared with horses without a tongue-tie. This increase in airflow was most likely attributable to a change in breathing pattern with the tongue-tie. The alteration of the breathing pattern with the tongue-tie may have been caused by discomfort or anxiety related to having the tongue tied out of the mouth. However, we were unable to detect a significant effect of a tongue-tie on peak inspiratory or expiratory tracheal or nasopharyngeal resistance, minute ventilation, tidal volume, or respiratory rate. On the basis of these results, application of a tongue-tie did not improve upper airway function in horses that had normal respiratory function.

Many racehorses perform with their tongues tied out of the mouth in an attempt to improve upper airway function and, therefore, performance. Often the reason for poor performance is unknown, and the tongue-tie is used as a palliative measure. To our knowledge, no scientific data is available regarding the effect of the tongue-tie on upper airway function in horses. However, research in other species has revealed that activation of the genioglossus muscle, the major muscle that protrudes the tongue, dilates and stabilizes the upper airways.[3-9]

A basic understanding of the anatomy of the tongue is helpful to understand why the genioglossus muscle is an important airway dilating muscle and the possible rationale, or lack thereof, for using a tongue-tie in horses with nasopharyngeal instability. Intrinsic and extrinsic muscles control the position and action of the tongue. The intrinsic muscles are located entirely within the tongue, and they alter the shape and rigidity of the tongue.[10] The genioglossus and hyoglossus are 2 extrinsic tongue muscles that are innervated by different branches of the hypoglossal nerve.[3,7] The genioglossus is a fan-shaped muscle that lies within and parallel to the median plane of the tongue.[10] The genioglossus muscle originates from the medial surface of the mandible just caudal to the symphysis and is innervated by the medial branch of the hypoglossal nerve.[10] A large tendon runs throughout the muscle. Muscle fibers radiate rostrally toward the tip of the tongue, dorsally, and distally toward the root of the tongue.[10] The hyoglossus is a flat wide muscle that lies in the lateral portion of the root of the tongue. The hyoglossus originates from the lateral aspect of the basihyoid bone and from portions of the stylohyoid and thyrohyoid bones and is innervated by the lateral branch of the hypoglossal nerve.[10] Contraction of the hyoglossus muscle causes the tongue to retract.[10] Contractions of both the genioglossus and hyoglossus muscles depress the tongue.[10] Contraction of the caudal genioglossus fibers protrude the tongue; the cranial fibers will retract the tip of the tongue.[10]

The roll of the genioglossus muscle in pharyngeal dilatation and stabilization has been studied extensively in many species, including humans. Many studies have revealed that respiratory-related electromyographic activity recorded from the genioglossus muscle in humans and animals increases in response to hypoxia, hypercapnia, and airway occlusion.[3,12-20] Electrical stimulation of the genioglossus muscle dilates and stabilizes the pharynx.[4,6] In addition, stimulation of the hypoglossal nerve dilates the pharynx, improves pharyngeal stability, and decreases the negative pressure necessary to collapse the airway.[3,7,8] Results of a study in humans indicated that active tongue protrusion by the subjects increased the cross-sectional area of the hypopharynx, oropharynx, and velopharynx, as measured by use of endoscopy.[9] This information led us to the hypothesis that pulling the tongue out of the horse's mouth and tying it would indeed dilate and stabilize the pharynx. However, passive traction on the tongue may be quite different than active contraction of the genioglossus muscle.

Recent information from studies performed in rats and humans suggests that during intense breathing efforts, the genioglossus and hyoglossus muscles are coactivated.[3,14-16] Hypoxia, hypercapnia, and airway occlusion caused parallel increases in electrical activity of the protrudor and retractor muscles of the tongue.[3,14-16] This activation consistently induced a net retraction force when the genioglossus and hyoglossus muscles were coactivated.[3,8,14] Despite causing tongue retraction, coactivation of the protrudor and retractor muscles resulted in improved airflow function and enhanced stability of the pharynx.[3,8] These results seem somewhat contrary to previous studies, which indicated that protrusion of the tongue was important in upper airway stability.[4,5,9] Indeed, contraction of the genioglossus muscle results in protrusion and depression of the tongue.[3,10] Contraction of the hyoglossus also causes depression of the tongue in addition to retraction.[3,10] Therefore, tongue depression may be the critical force needed to dilate and stabilize the pharynx.[3]

We measured upper airway function in exercising horses that had normal upper airway function with and without a tongue-tie. We were unable to detect a significant difference in airway function between these 2 groups. Our inability to demonstrate efficacy of the tongue-tie may relate to the normal airway function of the horses studied. We used intense exercise as a method of increasing respiratory effort in the horses. It is likely that the upper airway dilating and stabilizing muscles were functioning appropriately in these horses, because they had no evidence of upper airway abnormalities. If the genioglossus muscle was functioning appropriately, perhaps we should not have expected to detect a change in upper airway function with the application of a tongue-tie. It may be useful to investigate the effect of the tongue-tie in horses that have upper airway dysfunction. More likely, our inability to measure an effect of the tongue-tie on upper airway function may be attributable to the mechanism of action of the genioglossus muscle during breathing. Application of a tongue-tie involves pulling the horse's tongue out of the mouth and tying it to the mandible or the bridle. This action is distinctly different from contraction of the genioglossus muscle. The tongue-tie may cause protrusion of the tongue but not depression of the tongue. Depression of the tongue may indeed be the critical action of the genioglossus and hyoglossus muscles in creating upper airway stability and dilatation.

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[a] Digital VHF Telemetry System, MI403A, Hewlett Packard, Palo Alto, Calif.

[b] Polyethylene tubing, Baxter Scientific Products, McGraw Park, Ill.

[c] Pressure transducers, DP-45-22, Validyne Engineering Sales, Northridge, Calif.

[d] Laminar flow straightener element, Merriam Instruments, Grand Rapids, Mich.

[e] Model FP-2-37-10/77, Fisher & Porter Co, Warminster, Pa.

[f] Labview, National Instruments Inc, Austin, Tex.

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