The Mystery of The Missing Lamellae

At the Bowker Lectures

By Cristina Wilkins, Editor

A recently published article in the Journal of Equine Veterinary Science suggests that our knowledge of equine anatomy may be based on outdated findings and needs to be revised.

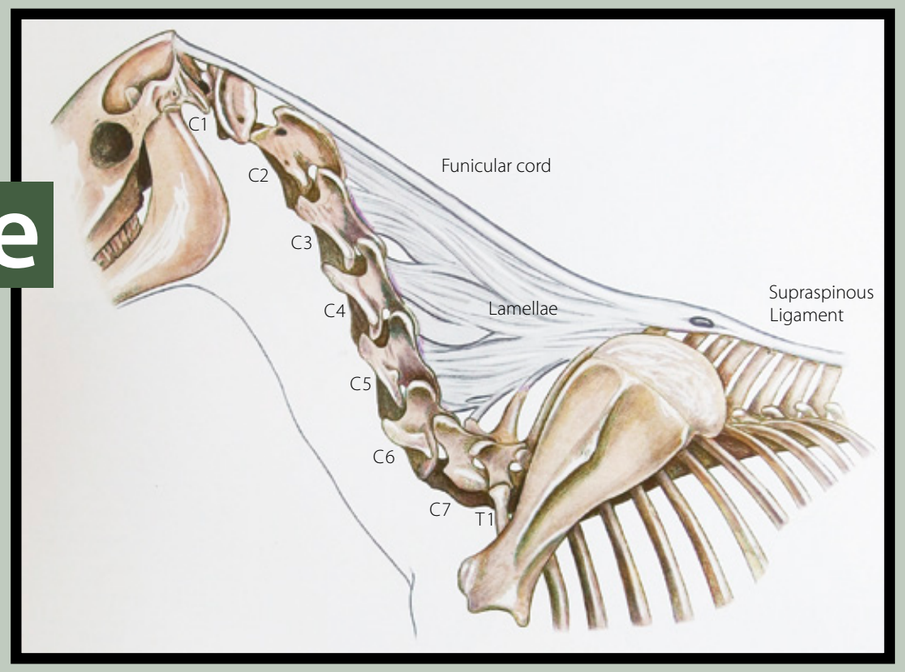
The paper centres around significant variations found in the nuchal ligament lamellae, which do not match conventional anatomic descriptions.

Australian researchers Sharon May-Davis and Dr Janeen Kleine presented their findings and explained the possible affect on horse's health and performance at the recent Bowker Lectures in Merrijig, Victoria.

In great demand as a lecturer, both in Australia and abroad, Sharon May-Davis is a respected research scientist and equine therapist particularly passionate about researching gross anatomy and how it impacts on equine performance. The study's co-author, Dr Janeen Kleine, is a paediatric and obstetric osteopath that mostly works with human patients, but has become increasingly interested in equine anatomy and applying her knowledge to the equine.

May-Davis began this fascinating and engaging presentation by defining the nuchal ligament, a two part ligament. The top part is known as the funicular cord, a very tough rope-like ligament that runs along the top of the neck, connecting the horse's poll to the withers, where it joins to the supraspinous ligament that runs along the top of the spine, all the way to the tail. The second part of the nuchal ligament is known as the lamellae, a triangular sheet-like ligament that splices into the funicular cord, and spreads down to attach to and support the cervical vertebrae.

According to the anatomy books that, to date, have served as study reference to veterinarians and practitioners around the world, the nuchal ligament lamellae attaches from C2 to C6 or C2 to C7. However, in the researchers' experience, the attachments to the last two vertebrae in the neck (C6 and C7) are completely absent, with some specimens also presenting with weak and feeble attachments to C5.



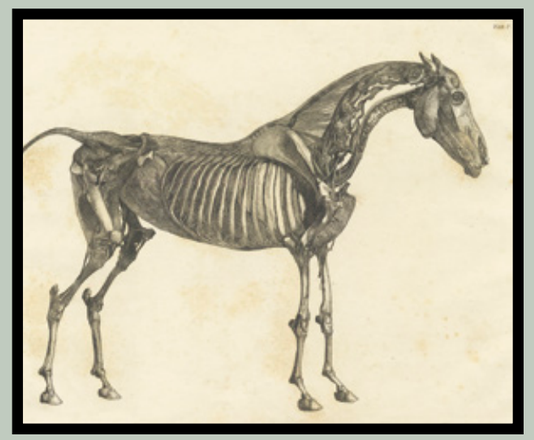
> "Thinking about how the lamellae attaches and knowing what we know about how the neck moves, the loss of suspensory struts has to have an impact on performance and may be compromising other structures.

Overview of the history of anatomic study of the equine:

Sharon May-Davis gave historical overview of our knowledge of anatomy which dates back to very elaborate and artistic drawings by 17th Century artists such as Snape. After studying his works, which show horses in exaggerated postures and beautifully detailed backgrounds, it would be fair to conclude that appealing to the sensibilities of the time may have been more important than describing the anatomy accurately. However, May-Davis believes that it is likely that Stubbs (1777) did see complete lamellae in his dissections. The works of Stubbs have remained very influential because they depict some skeletal malformations which strongly suggest he was giving a true anatomic account of horses.

More recently, however, 20th Century artists, such as Sack and Popesko, whose illustrations are used as reference today by the most prestigious veterinary schools and are widely cited in the scientific literature, also depict a complete nuchal ligament lamellae that is very different to what May-Davis and Dr Kleine have ever seen in practice.

Supported by a single dissection case of a feral donkey with a clearly complete lamellae, May-Davis and Dr Kleine suggest that earlier anatomists may have well seen a complete lamellae in horses. They propose the anatomical changes may be the result of selective breeding, and has simply been treated as 'incidental' and remained unreported. Modern day anatomists may have been too heavily influenced by previous publications, rather than noting and investigating any variations they found during dissections.



FAR LEFT: Andrew Snape, serjeant farrier to the British king Charles II published in 1683 The Anatomy of an Horse, the first equine anatomy book in English.

LEFT: An engraving by George Stubbs (1766). Son of a currier (leather tanner) scientist and artist, Stubbs dissected horses and made detailed drawings of each layer. His remarkable and detailed engravings have remained very influential and are considered realistic. It is likely that these early anatomists did see a complete lamellae in the horses they dissected.

ABOVE: Prof Peter Popesko published the first edition of his Atlas of Topographical Anatomy of the Domestic Animals during the 1970s. Popesko's depiction of the nuchal ligament lamellae shows clear and definite attachments from C2 to C7. Did Popesko see complete lamellae during dissection or was he influenced by earlier anatomists?

Function and dysfunction

The peer reviewed paper reports on 35 dissections performed over a two-year period. However, May-Davis had noticed the same in every one of hundreds of previous dissection specimens. "I was told it was incidental so I had not questioned it before," May-Davis said. "It was only when I started to work with Dr Janeen Kleine that we decided to formally document and publish this mysterious, 'missing' lamellae."

As May-Davis explained to the conference delegates, the nuchal ligament's structure and function can be visualised as a suspension bridge (See illustration). The funicular cord serves as the main cable, the lamellae form the suspension cables and the bridge's deck is made up by the cervical vertebrae (Note for illustration: anchors are the skull and supraspinous processes; the pylons are the legs).

If we refer to this suspension bridge comparison, we can see that, as well as suspending the vertebrae to counteract the effect of gravity, the lamellae also helps to control twisting (axial rotation) of each individual vertebrae except C1, adding stability. Structurally, it makes sense that all the vertebrae should be firmly supported as is depicted in the anatomy books. So, why are two and in some cases three vertebrae not fully supported in so many specimens? Is this normal anatomy, or is it compromising stability and normal function?

An osteopathic perspective

Dr Kleine took the stage to explain why this absent lamellae warrants investigation: "Thinking about how the lamellae attaches and knowing what we know about how the neck moves, the loss of suspensory struts has to have an impact on performance and may be compromising other structures. As an osteopath, I am particularly interested in how the horse's body will attempt to compensate for this lack of support. Is this absent lamellae altering or impairing function in the lower cervical neck in every horse or is this normal anatomy?"

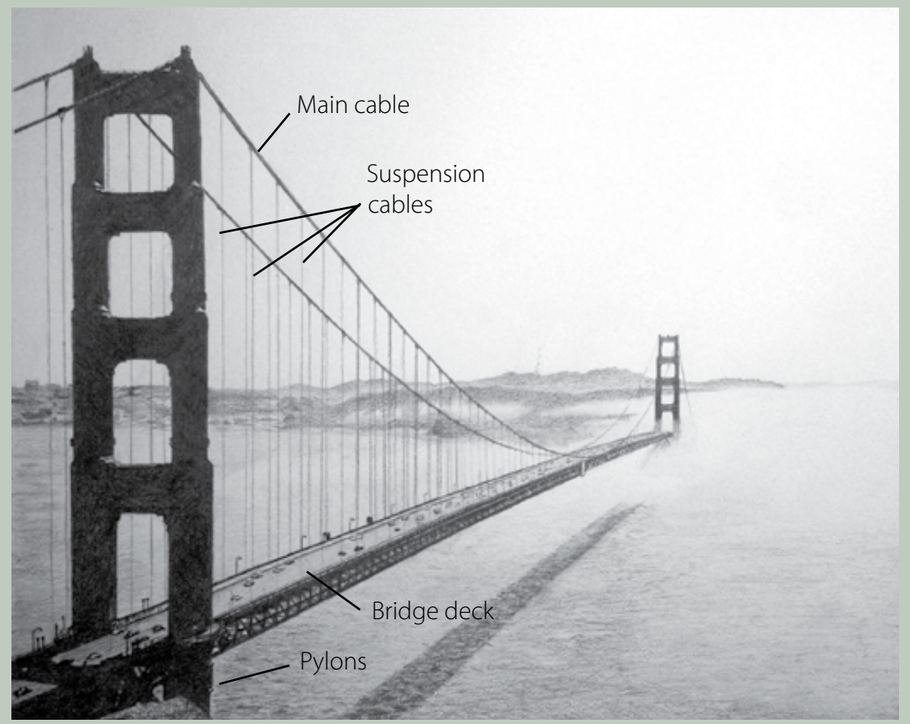
Dr Kleine summarised for the delegates the principles of osteopathy, a manual medicine practice with a strong concept of somatic (body) dysfunction, i.e. impaired or altered function of related components of the body, the bones, joints and myofascial tissue and structures, and their related vascular, lymphatic and neurological systems, as well as the organs (viscera).

From an osteopath's perspective, the body (all that is contained under the skin) is a unit and possesses self-regulatory mechanisms. When faced with an imbalance, it will attempt to compensate and find homeostasis. "Structure governs function and vice versa," said Dr Kleine. "So, if we have changes in the structure of the neck, how is this affecting function? An altered function of the neck will have an effect further down the limb, back along the spine and forward to the head."

Dr Kleine remarked there has been quite a lot of study into segmental motion in the equine neck.

The greatest range of lateral bending is firstly, C7-T1 and secondly, C6-C7; flexion and extension again the articulations from C5-T1 with axial rotation greatest at C1-C2 (due to joint specificity) and C6-C7, C7-T1 second and third respectively.

In both researchers' opinions, the large range of movement may be due to the lack of lamellae, what is not as clear to them is whether it is a result of the missing lamellae or it is contributing.



The nuchal ligament's structure and function can be visualised as a suspension bridge such as the famous Golden Gate in San Francisco (above).

The tough, rope-like funicular cord and supraspinous ligament represent the main cable running along the horse's entire spine which would equate to the bridge's deck.

The nuchal ligament lamellae fibres splice into the funicular cord and attach to the cervical vertebrae.

Just like the suspension cables, the lamellae fibres hold the vertebrae in place, counteracting gravity and control twisting (axial rotation).

The researchers argue that it makes more sense that all cervical vertebrae should be well supported, just like depicted in conventional anatomy books.

Just as we would worry if we drove into a suspension bridge with broken, feeble and missing suspension cables, the researchers are concerned about the affect on the health and performance of modern horses. This is very relevant because so much importance is placed on head and neck posture in different disciplines.

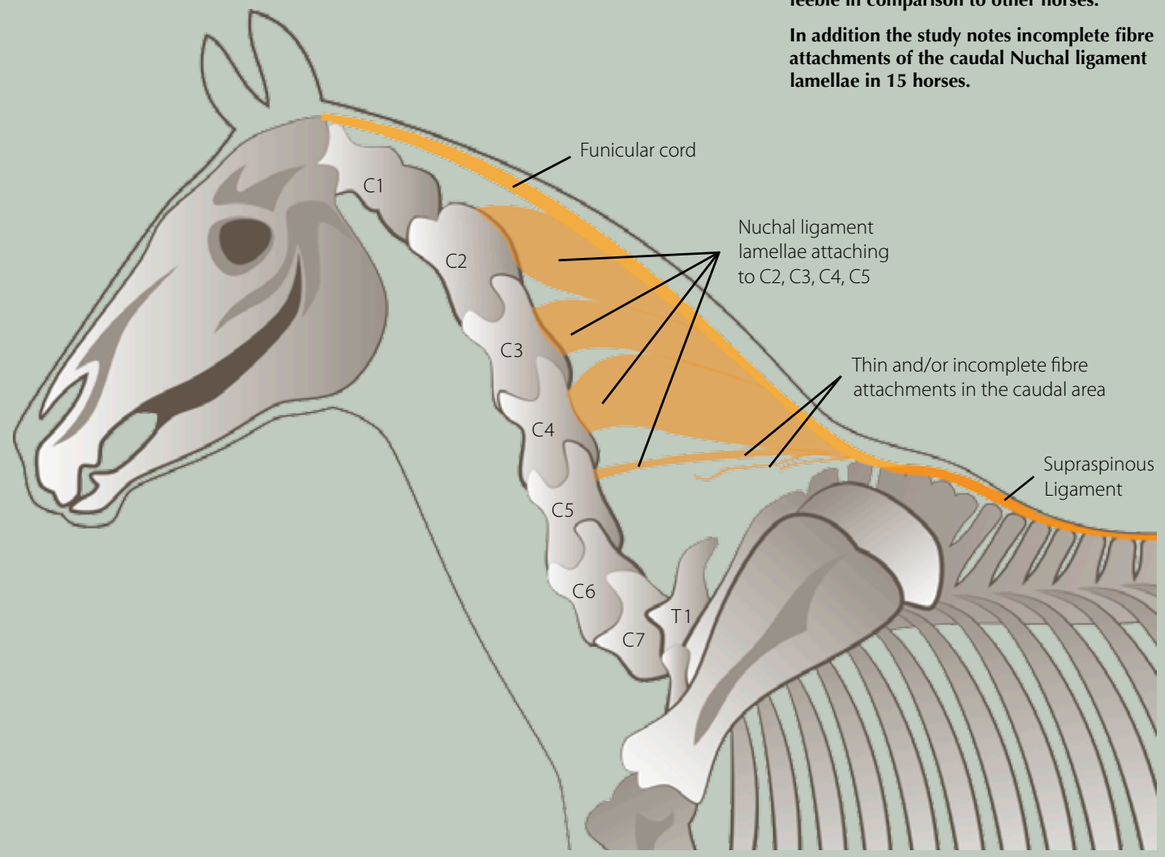
> Current imaging technology does not allow us to see clearly the lamellae in a live horse, although the researchers are working with technicians and developers on possible solutions.

LEFT: Current conventional anatomy knowledge that is taught to veterinarians and practitioners describes the nuchal ligament lamellae attaching from C2 to C6. Image source: Tug of War: Classical versus "Modern" Dressage, by Gerd Heuschmann.

BELOW: The study by Sharon May-Davis and Dr Janeen Kleine reports that of the 35 horses observed in dissection, all 35 expressed attachment points of the Nuchal ligament lamellae from C2 to C5 as shown below. (Image source: shutterstock, adapted by Cristina Wilkins).

It notes that in 9 horses, the attachment of the lamellae to C5 was indeed, thin and feeble in comparison to other horses.

In addition the study notes incomplete fibre attachments of the caudal Nuchal ligament lamellae in 15 horses.



Effect of pressure

Kleine also spoke about the effect that gravity, and loading from the forelimb may potentially have on these less-supported vertebrae. "Researchers are certainly reporting cervical joint disease (arthritic changes) in this area of the neck with the increasing age of the horse."

Increased movement in this area will, over time, cause wear and tear to these joints, and potentially pressure to the spinal cord and to the nerves as they leave this part of the spine. Spinal cord pressure in this area may cause nerve changes in the hindquarter, whereas pressure to the nerves as they leave the spine can compromise the brachial plexus (the network of nerves that run from the spinal cord to the forelimbs). Therefore, these effects of pressure may lead to changes in locomotion activity in both the hind and the forelimb.

"We also know from studies that when there is increased loading from the funicular cord higher on the neck, we will see insertional desmopathies (disease at the point where the ligament joins the bone) in C2," continued Dr. Kleine. "And I suspect that this may be the result of taking a load that is not supported further down."

"As an osteopath, understanding more of the picture helps us understand what is under our hands. Horses will use their limbs to minimise stress in any given area; probably because the limbs have a greater degree of movement. An altered muscle recruitment pattern in a limb will biomechanically alter the flight of the limb's arc and, therefore, the movement pattern will be altered."

How can we help?

The presentation became very relevant to all practitioners when May-Davis changed the rein to present ways in which therapists and horse owners could help horses compensate for this apparent lack of support and stability.

"If we have a structural compromise," said May-Davis, "Then maybe we can help horses by developing the muscles involved in intersegmental rotation. These are not going to be those long superficial muscles of the neck; the brachiocephalic and splenius aren't going to hold the cervical vertebrae in place. I am talking about deeper, ventral muscles and, particularly, the longus colli."

The longus colli is a muscle that is slung like a hammock between the vertebrae from C1 to T5, and supports the base of the neck by stabilising, fixating, flexing and rotating the vertebrae. It is a postural or cybernetic muscle that is very rich in proprioceptive innervation (i.e. it responds immediately to external forces). In cybernetic muscles, a single motor neuron services between 20 and 30 myofibrils (the fibres that contract and make up the muscle), whereas in the large 'gymnastic' muscles, there is one motor neurone every 1,000 myofibrils. "If we can influence [cybernetic] muscle memory for just a few minutes a day," said May-Davis, "we can change muscle very quickly and the effect can be long-lasting.

Nothing will bring the nuchal ligament lamellae back but, if we focus on strengthening the multi bundled longus colli, we can help support the cervical and thoracic vertebrae from a ventral (underside) perspective. A simple way to achieve this is by allowing horses to browse, a natural behaviour in the wild."

The Brachial Plexus

The brachial plexus is a network of nerves that supply the neck and fore limbs. The nerves branch out from C5, C6, C7 and T1. (See illustration on right).

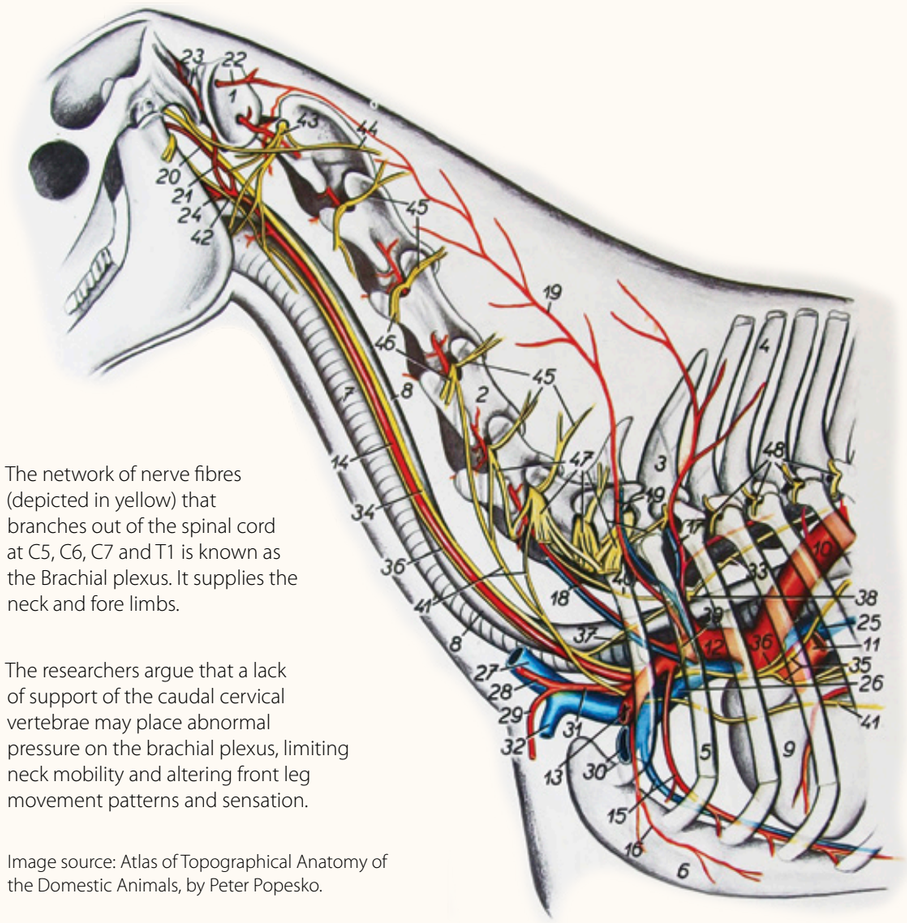
The researchers question whether a lack of lamellae support in exactly this area of the neck impacts on the nerve supply to the horse's forequarters and could be relevant when diagnosing and treating limb issues.

"If we are getting changes to the nerve supply of muscles," said Dr Kleine. "Are we getting altered recruitment patterns of the muscles that are being supplied?"

"Considering that loss of one neural fibre up in this area can de-nervate hundreds of muscle fibres further down the limb," she continues, "knocking out some of the nerve supply means the muscles may not function as well as they should."

This, Dr Kleine explained, could show up clinically as:

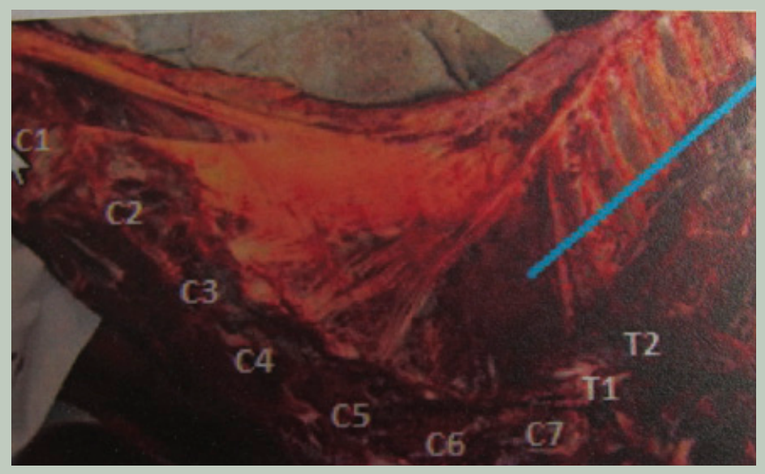
- limited mobility, such as the horse not side bending as much as we would like,
- an altered gait due to pain
- a shorter stride that mimics a lower limb lameness.
- We may see pain,
- altered muscle strength,
- altered sensation in the fore limb which may manifest as stamping (pawing) the foot or biting at the foreleg or,
- patchy sweating on the neck or thorax.

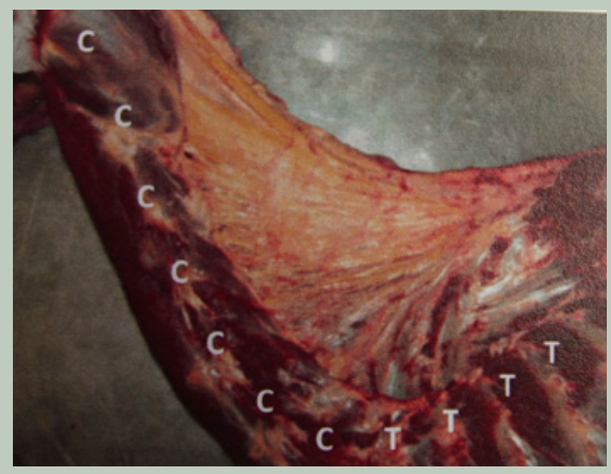


The network of nerve fibres (depicted in yellow) that branches out of the spinal cord at C5, C6, C7 and T1 is known as the Brachial plexus. It supplies the neck and fore limbs.

The researchers argue that a lack of support of the caudal cervical vertebrae may place abnormal pressure on the brachial plexus, limiting neck mobility and altering front leg movement patterns and sensation.

Image source: Atlas of Topographical Anatomy of the Domestic Animals, by Peter Popesko.





LEFT: This feral donkey specimen displays a complete Nuchal ligament lamellae, in the same way as described in conventional equine anatomy books. This contrasts with the researchers findings. Every one of the 35 recorded specimens show no attachment to C6 and C7.

FAR LEFT: The equine Nuchal ligament lamellae attaches from C2 to C5, as shown by this 5 year old Thoroughbred gelding, on of the specimens recorded in the study.

Photos courtesy of Sharon May-Davis and Dr Janeen Kleine.

Previous issues of Horses and People have reported on browsing in horses, and the research being conducted into foraging behaviour by equine nutritionist and regular contributor Mariette van den Berg, also a presenter at the Bowker Lectures. In Australia, where access to pastures containing different varieties of trees and shrubs is fairly common, owners have reported their horses don't just graze the grasses below, but also stretch up to browse on higher trees and shrubs.

May-Davis soon realised the connection between the study's findings and a technique she had been experimenting with since 2003 of feeding horses hay high. "That's when the jackpot hit" she said. Placing a hay net at between eye and poll height (depending on the horse's flexibility) is one way we can mimic the browsing posture seen in feral horses. May-Davis showed photographs of semi-feral herds of Konik horses browsing under the shade of big trees to explain that the head-high browsing posture is, in fact, activating all the deep ventral muscles.

"There's a discussion that horses shouldn't eat high, that they are grazers," said May-Davis. "But, the trouble is that in a natural setting horses will browse, sometimes up to 20 minutes or longer, and what I've always found pretty pertinent is how square they are all standing while they browse (as opposed to having one leg forward and the other back when they are grazing). The browsing posture engages and strengthens the ventral muscles of the caudal cervical and cranial thoracic vertebrae, particularly the Longis colli and the ventral intersegmental muscles between C1 and T5. These are all little stabilisers. They are cybernetic muscles that ballerinas use to remain in posture."

"The results of hay high have been exciting for me and I have not seen any negative side effects; well none apart from a miniature companion pony who could not reach the hay."

Next month, I will report on another fascinating Bowker Lecture that centred on laterality by Dr Kerry Ridgway, an internationally renowned lecturer in integrative veterinary and conventional medicine that has specialised in equine performance issues and postural rehabilitation.

About the lecturers:

Sharon May-Davis, BAppSc, MAppSc. Sharon May-Davis began riding at age four and stopped competitive riding in her late 20's. Soon afterwards, she began her academic journey that included the building of equine skeletons and research. Her innovative therapy practice saw the State and Australian Champions in seven different disciplines, of which she had a part in the selection process in three. Now, Sharon is primarily an equine scientist and lecturer in Australia and overseas, with published works in the Journal of Equine Veterinary Science, Australian Veterinary Journal and Centre for Veterinary Education.

Dr Janeen Kleine, BClinSc, BOstSc, MOstSc. Dr Janeen Kleine has become increasingly interested in equine anatomy, and the application of osteopathic principles and techniques to horses. This has led to her dissecting horses to enhance her understanding of their anatomy and biomechanics. Janeen is now venturing into the world of treating and attempting to understand the musculoskeletal system of horses, and sees a strong correlation between her equine and paediatric human patients.

Developing core strength, the easy way...

Sharon May-Davis presented three case studies where the hay-high technique, which mimics the natural browsing posture, was used in conjunction with other therapies and treatments to rehabilitate injured horses. (See photos on right).

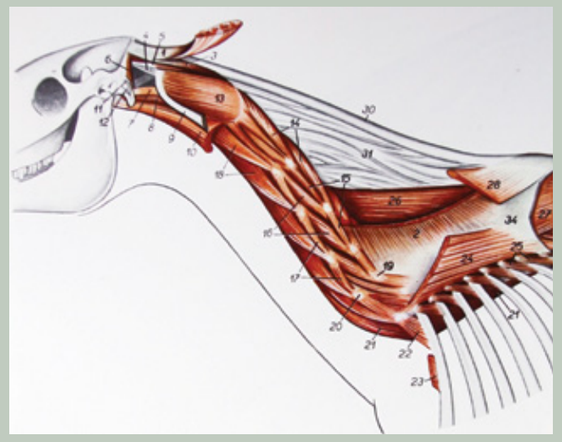
While eating hay high the horses were more willing to stand posturally square and activate core muscles to elevate the base of the neck and the front of the ribcage in a similar way that describes a horse in self-carriage.

One hay net per day was tied at approximately eye to poll height, depending on the horse's ability and flexibility.

As the horse reaches up, he will sometimes rotate the head one way and the other to pull the hay out. It is important to note that, in this posture and, contrary to popular belief, the back does not 'dip', but is stretched up and forward utilizing core muscles. Some hay will fall on the ground and the horse will alternate between eating high and eating low, further increasing the beneficial gymnastic effect.

Anecdotally, owners have reported that hay high helps to improve hoof development, preventing or limiting the formation of club feet during rehabilitation from severe injuries, as well as improving straightness and self-carriage in performance horses.

Courtesy of Robyn Larson-Shelton



ABOVE: 'Doc' a 13 year-old Arab gelding one week into hay high. The browsing posture engages and strengthens the ventral muscles of the caudal cervical and cranial thoracic vertebrae. Note how square Doc stands when browsing and how this contrasts with his usual grazing stance. Photos courtesy of Robyn Larson-Shelton.

LEFT: The Longis colli and the ventral (lower) intersegmental muscles between C1 and T5 are all little stabilisers rich in proprioceptive innervation that help maintain posture. Image source: Atlas of Topographical Anatomy of the Domestic Animals, by Peter Popesko.