“The Dilemma of the Absent Lamellae”

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“Variations and implications of the gross anatomy in the equine nuchal ligament lamellae.”

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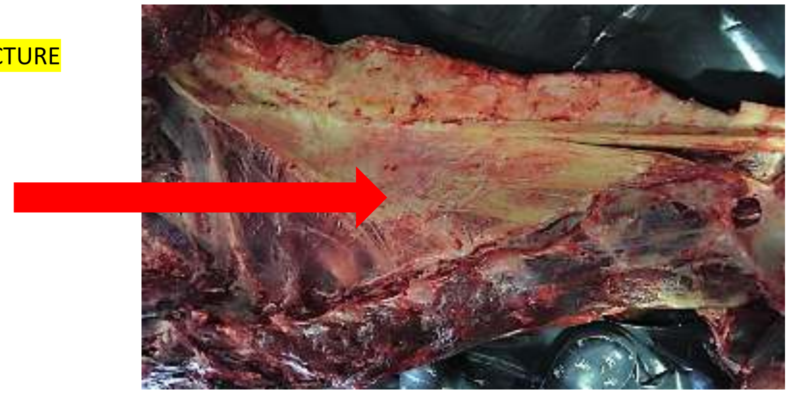
Early literature depicting equine anatomy began with stylised illustrations portraying anatomical structures in a congenial format. This study shows that modern day literature often reflects those early portrayals and in particular, the description and depiction of the Nuchal ligament lamellae (NLL) and its attachments from the 2nd to the 7th cervical vertebrae. In the dissection of 35 horses of no specific breed, were unrelated and of mixed gender and age, it was noted that the NLL was not attached to the 6th and 7th cervical vertebrae. Furthermore, the attachment of the NLL on the 5th cervical vertebrae was quite thin and feeble in 9 of those horses and that incomplete fibres were noted in the caudal attachments of the NLL in 15 horses. These variations do not correlate to those early depictions or to the majority of existing equine anatomical text. This new information on the equine NLL has functional and clinical implications, with particular reference in the way we currently understand the postural and locomotive properties of the equine neck and cervicothoracic junction.

NO NOT THIS Lamellae – THIS Lamellae

PLEASE PLACE A GOOD CADAVER PICTURE

OF THE HOOF LAMELLAE - LEFT

of the ARROW.



Introduction

According to Dyce, Sack and Wensing [1], the Nuchal ligament consists of 2 clearly defined paired sections; the 1st or dorsal portion is a thick cord (funicular cord) that attaches to the occipital crest and extends caudal and distal to the highest spines of the thoracic vertebrae. The 2nd portion (lamellae) forms a sheet filling the space between the funicular cord and the cervical vertebrae of which, the fibre bundles are closely interwoven with those of the funicular cord. These elastic bundles run cranial and ventral from the funicular cord and the spines of T2-T3, to attach to the dorsal spines of C2-C7 as depicted in Figure 1 by Popesko [2].

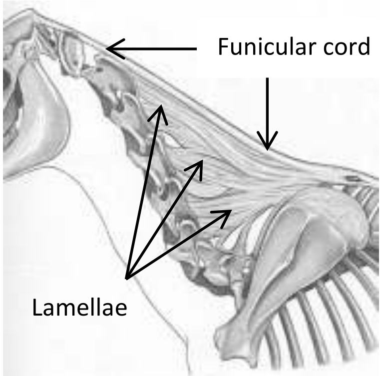


Figure 1. The Equine Nuchal ligament. Popesko [2]

This depiction of the equine Nuchal ligament lamellae has been around in various forms since the 1600’s, when early anatomists dissected and drew their findings with artistic licence. This inference is in relation to the need to satisfy human sensibilities without offending them with visual blood and gore. So in fact, what was often depicted may have been somewhat correct, but delivered in a fashion that would not be offensive. Take for example the work by Snape [3] and his depiction of the horse in 1683, Figure 2. The horse is upright, mouth gaping, looking at the artist with clouds rolling past in the background.

Figure 2. The Equine head neck and shoulder. Snape [3]

Now when Stubbs [4] drew equine anatomy in the late 1700’s, it was revered as a true account of the horse and veterinarians of the time regarded it as an anatomic textbook. However, his presentation of arched neck and pinned ears was also noted in his live oil paintings with amazing similarities. Although in all fairness, these early anatomists were not blessed with cameras, cool rooms or the tools to complete a dissection before the cadaver horse became repugnant. Hence why we are now in a position to re-address the Nuchal ligament lamellae and diverge away from early anatomic text and correct modern day literature, especially when the same drawing keeps reappearing over numerous decades in educational anatomic text!

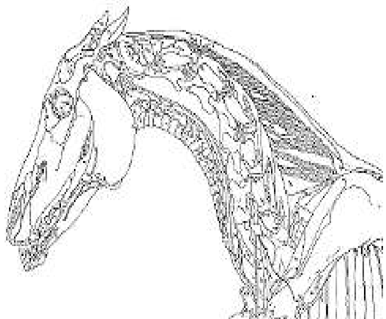


Figure 3. The Equine head and neck. Stubbs [4]

Methods

To achieve our goals, we unfortunately had to collect our observations from horses' post-mortem and the unfortunate 35, were of mixed gender with identifiable breeding, aged between 2-28 years. All the horses were euthanized for purposes unrelated to the study and in educational facilities. The integument (skin) and lateral neck muscles were carefully dissected on one side to reveal the Nuchal ligament funicular cord and associated lamellae within 48 hours of euthanasia. The horses were then placed in 3 categories according to the attachment points of the Nuchal ligament lamellae; C2-C7, C2-C6 and C2-C5 as per Figure 4a, 4b and 4c respectively.

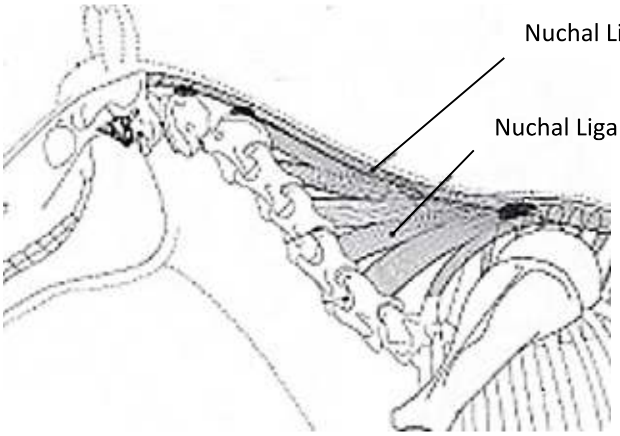


Figure 4a. The Nuchal ligament lamellae C2-C7

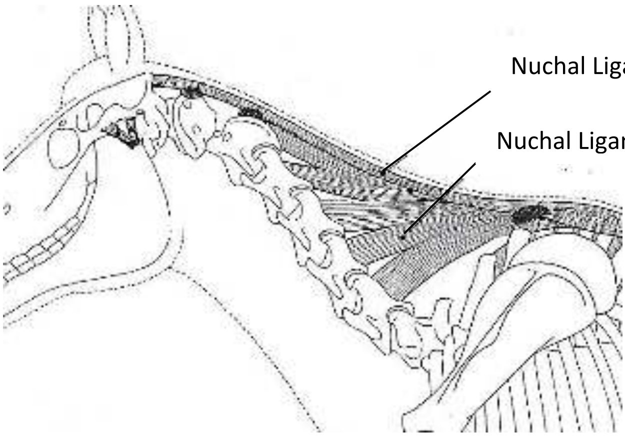


Figure 4b. The Nuchal ligament lamellae C2-C6

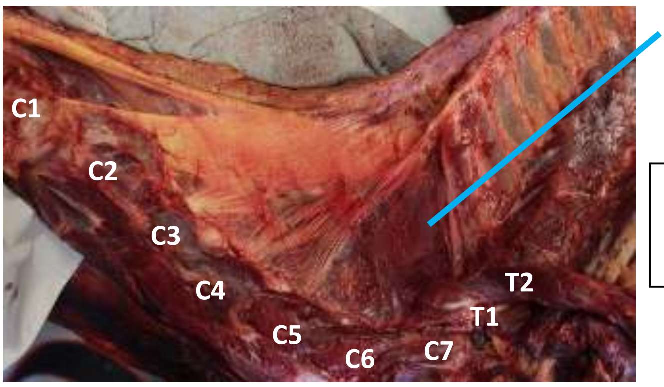


Figure 4c. The Equine Nuchal ligament lamellae attaching from C2 to C5 in a 5 year old Thoroughbred gelding.

Results

Of the 35 unfortunate horses observed, all 35 expressed attachment points of the Nuchal ligament lamellae from C2-C5 as shown in Figure 4c. At this point, the authors realised that they were about to attack centuries of conventional thinking. However, they trudged forward and it was further noted that in 9 horses listed in the C2-C5 category, the attachment of the Nuchal ligament lamellae to C5 was indeed, thin and feeble in comparison to other horses (Figure 5). In addition, incomplete fibre attachments of the caudal Nuchal ligament lamellae were noted in 15 horses (Figure 5).

In all 35 horses, the digitation between the attachments of the Nuchal ligament lamellae onto the dorsal spines of the cervical vertebrae remained in a clear sequential pattern (Figure 6).

Breed	No.	Gender Male/Female	C2-C7	C2-C6	C2-C5	Incomplete fibres
Thoroughbred (Tb)	18	7 M / 11 F			18 (4*)	9
Arabian	1	1F			1	
Quarter Horse (QH)	2	1M / 1F			2	
QH x Arab	1	1F			1	1
Morgan	1	1F			1 (1*)	
Brumby	1	1M			1 (1*)	1
New Forest Pony	1	1F			1 (1*)	1
Riding Pony	1	1M			1	
Shetland	1	1M			1	
Warmblood (Wb)	1	1M			1	
Wb x Tb	1	1F			1 (1*)	1
Standardbred	2	1M / 1F			2	
Aust. Stock Horse	2	2M			2 (1*)	1
Appaloosa	2	2F			2	1
TOTAL	**35**	**15M / 20F**			**35 (9*)**	**15**

(*) indicates the number of horses with thin and feeble fibre attachments to C5.

Table 1. Observations of the attachment points of the Nuchal ligament lamellae in 35 horses of mixed gender and identifiable breeding aged between 2-28 years.

Figure 5. A 12 year old Standardbred mare displaying thin and weak lamellae fibres attached to C5 plus incomplete lamellae fibres in the caudal cervical vertebrae.

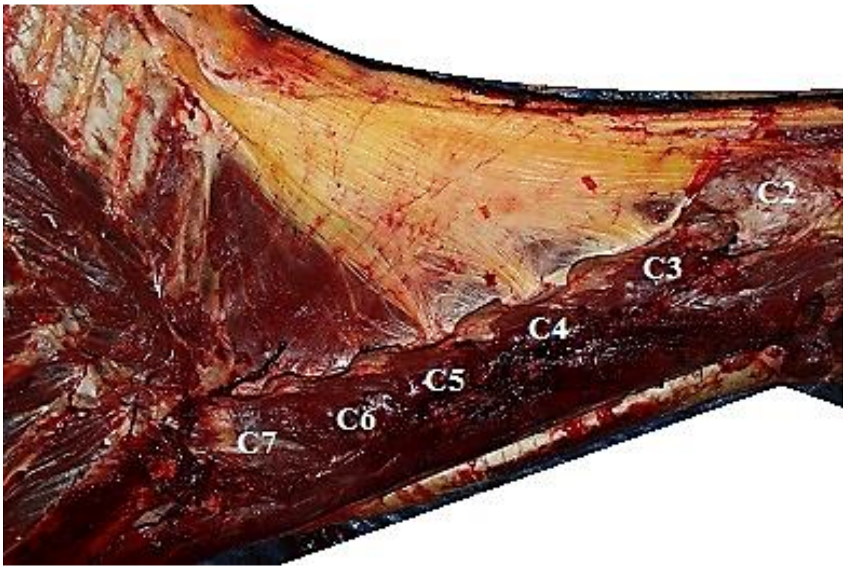


Figure 6. A 6 year old Thoroughbred gelding displaying a clear pattern of the lamellae bundles attaching to the dorsal spines of the cervical vertebrae forming sequential digitation.

Discussion

We are led to believe that a function of the Nuchal ligament is to passively counter the mechanical effect of gravity by supporting the head and neck, while epaxial cervical muscles are actively engaged [4]. In addition, the hypaxial cervical muscle Brachiocephalic relies upon the traction provided by the Nuchal ligament (funicular cord and lamellae) as a counterbalance on the cervical vertebrae in order to bring the foreleg forward [5]. This reduces the muscular work that would otherwise be required to hold the head above the ground and it is likely that there are dynamic links between the pendulum mechanisms of the limbs and that of the head/neck segment [6].

In light of the lamellae findings in this study, it could imply that epaxial cervical muscles may be recruited and activated abnormally in an attempt to maintain normal function of the neck and especially in the cervicothoracic region. If so, ramifications of abnormal muscle recruitment may then present in both the neck and or foreleg. Furthermore, it would be a reasonable assumption, that a greater load is placed upon the attachment points from C2-C5 during locomotion and that the caudal NLL has no influence in lowering the head to the ground for grazing purposes. Therefore, the stability of the 6th and 7th cervical vertebrae is in fact compromised and these assumptions are even more relevant when the lamellae attachment on C5 is thin and feeble as noted in Figure 5.

With this in mind, it could therefore be postulated that the absence of the lamellae attachments to C6 and C7, may in fact compromise the stability of cervical areas that are already under increased load in normal biomechanics. Anatomic studies have reported a common occurrence of arthropathy in the caudal cervical articular process joints (APJ's) in horses of any breed, older than 4 to 5 years [4,7]. Furthermore, Ross [7] reports that remodelling of the joints occurs primarily at C6 and C7, while Down [8] found arthropathy of the caudal cervical APJ's at the C5 – C6 level. These studies found no association between arthropathy of the APJ's and case subject details (breed, age, sex, usage); however, a positive correlation with increasing age was noted. Osteoarthritis of the APJ's, especially in the more caudal aspect of the cervical spine, may result in an associated enlargement of the joint capsule and subsequent pressure to the spinal cord or nerve roots [4, 9]. Given the prevalence of this condition, understanding the gross anatomy of the NLL may lead to a further understanding of the pathogenesis of APJ arthropathy in the caudal cervical vertebrae.

Conclusion

This study showed that of the 35 horses dissected, all 35 displayed an absence of the Nuchal ligament lamellae attachment to C6 and C7. In addition, 9 horses exhibited thin and feeble attachments on C5, whilst 15 had incomplete fibres in the caudal neck. As the function of the Nuchal ligament lamellae is both a static and dynamic component of a horse's posture and movement, it would be appropriate to revaluate its functional role. Furthermore, these findings change our understanding of caudal cervical vertebrae mechanics and therefore the pathogenesis of clinical conditions in this region.

So one must begin to wonder what happened to the lamellae if it was originally seen and drawn in 1777. Perhaps we may need to see if this anomaly appears in species close to the 64 chromosome equus caballus that we now know as the horse?

What does DONKEY say?

“Donald the Donkey” was a mid-teens feral Ass from Tennant Creek NT. Equus asinus or “Donald”, was approximately 12 hh and typical of the feral Asses currently running around in the Top End of Australia. His heritage began in 1866, when donkeys were brought out to Australia as pack and or haulage animals over the arid environment that soon became their home. “Donald” was one of what is believed to be 5 million feral donkeys currently running around in arid or remote areas of Australia today. They are intelligent, hardy and similar to horses with 2 less chromosomes (horse 64 – donkey 62). “Donald the Donkey” is the first investigative step outside of Equus caballus to the “Dilemma of the absent Lamellae” and his Nuchal ligament was superb! (Figure 7).

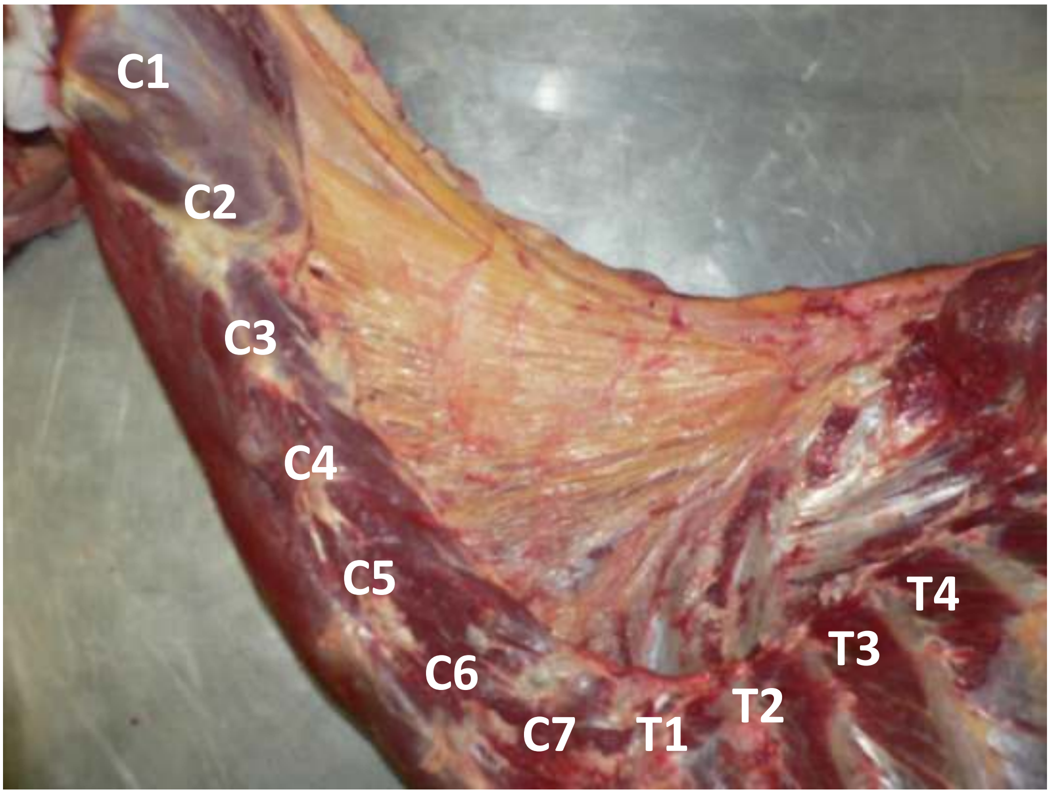


Figure 7. “Donald the Donkey”, a mid-teens feral Ass from Tennant Creek NT.

When compared to modern day horse, “Donald’s” Nuchal ligament lamellae were completely intact with little to no digitation between the vertebrae. When a subjective comparison was made between the Nuchal ligament funicular cord in this donkey and previously dissected horses, the funicular cord appeared denser and dimensionally larger than a horse of a much larger size.

With this in mind, it would therefore be relevant to investigate other related species such as the Przewalski and the Konig pony of the Netherlands (a through back to Tarpons).

So what can we do about it?

Nothing will bring the Nuchal ligament lamellae back.

The absence of the lamellae is present at birth and does not regenerate as the horse progresses in years. This leaves a distinct gap in supportive caudal neck tissue (just like looking at a suspension bridge with support cables missing). However, if we look at those structures involved along the ventral aspect of the neck, we can focus on strengthening the multi bundled Longus colli muscle that aids in supporting the cervical and cranial thoracic vertebrae from a ventral perspective [11]. This can be achieved by allowing the horse to browse, a natural process for horses in the wild (Figure 8).

Figure 8. Wild Konig ponies of the Netherlands browsing, note foliage height from constant use.

Figure 9. "Wishes" in rehab post broken scapula - note posture.

Although this is not possible in many cases due to the stabling of horses, there is an opportunity to place the hay higher so that the horse can browse, similar to those in Figure 6, just by placing the hay net higher in stables or trees. Note "Wishes" a 7 year old Arabian mare in Figure 9 and the placement of her feet in relation to functional equilibrium and balance.

What is important to understand about the Longus colli muscle is that it is a cybernetic muscle, rich in proprioceptive innervation [12}. It functions as a source of postural and locomotive information transmitting the muscle's state of tension to the brain. This rich innervation is achieved via one neuron servicing 20-30 myofibrils in contrast to gymnastic muscles, such as the Triceps being serviced with one neuron every 1000 myofibrils [11]. In human terms, muscles such as the Longus colli train a dancer's posture and this postural information remains so, even later in their twilight years, but this doesn't apply to horses (Figure 10) or does it?

Figure 10. Oh, to train a horse to dance - **Tchaikovsky's Pony Pond!**

In the horse, the Longus colli muscle and its thoracic portion is a paired hypaxial muscle that is located along the ventral surfaces of the cervical vertebrae from C1 to T5 or T6; it is a short bundled multifascicular muscle that functions to stabilise, fixate, flex and rotate the vertebrae [12-15]. However, as the Nuchal ligament lamellae aids in limiting axial rotation, this implies that C6-C7 and C7-T1 have a greater ROM than C2-C3, C3-C4, C4-C5 and C5-C6, and this was confirmed by studies conducted by Zoldas et.al. [16]; this could explain why we have such a significant amount of arthropathy in the caudal and cranial facet joints of the caudal cervical vertebrae as reported by Ross et. al [17] and Down et. al [18].

Figure 11. Konig pony standing square to browse in the wild.

So how can hay high help? The theory behind placing the hay between eye and poll height is to elongate and stretch the ventral muscles of the cervical and thoracic vertebrae and place a gentle traction on the cervical and cranial thoracic intervertebral joints. This may assist in a number of areas;

- Improve ventral neck stability that has been brought about by low posture.
- Support cervical and thoracic intervertebral joints by strengthening the Longus colli muscle.
- Support a greater ROM, especially in the caudal cervical and cranial thoracic vertebrae.
- Retrain horses posturally as they stand primarily square to browse and this will aid in **head to toe equilibrium** (Figures 11, 12a,b,c).
- Aid neck to poll connections by activating head; obliques and rotators (Figures 12a,b).

Does placing the hay high have any negative side effects?

To date - NO! (except for miniatures who can't reach)

Figures 12. "Doc" 13 yr old Arab, 1 week into hay high browsing.

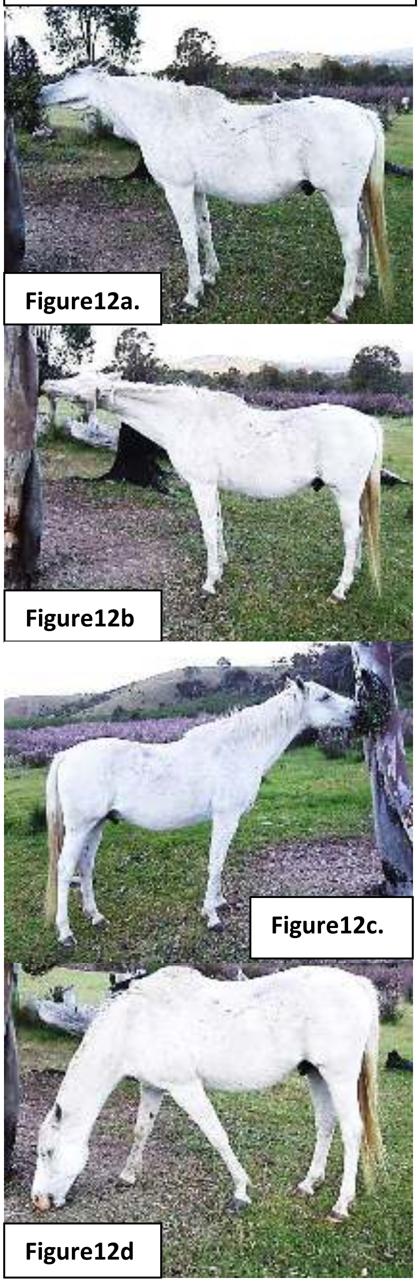


Figure12a.

Figure12b

Figure12c.

Figure12d

What has been noted is that horses are more willing to stand posturally square and activate core muscles to elevate the caudal cervical and cranial thoracic vertebrae to reach the hay, otherwise known as – **self carriage.**

The top line of the back does not dip, but engages to pull on the hay net counterbalanced by activated core muscles (Figure 12c). Once the horse has pulled out sufficient lengths of hay, it then lowers its head to chew on it in a normal position, thus activating the TMJ correctly. The horse will then re-engage its browsing from the high hay net just like those in the wild.

The next added advantage is the horse will eat the hay scraps on the ground - note the split leg grazing position in Figure 12d. This is less desirous, but the horse will then resume browsing posture to reach the hay net and this is desirous. A multiple stretching regime is activated by just placing one hay net per day around **eye to poll** height depending on the horse's ability or stiffness. This browsing pattern of **approximately 30-45 minutes per day** simulates wild horses and may even aid in hoof development. **As subjective and anecdotal reports indicate; horses hooves either lower in the heel when too high or grow heel when too low.**

This hay high browsing has also been translated into the ridden horse, whereby subjective information has noted straightness under saddle, square halts, and the horse's ability to reach for the bit and remain; soft, subtle and responsive. Muscle therapists have also noted the horse's softer tissue structures and posture. In one stable, the therapist's workload has been reduced and this may not good news for muscle therapists? However, this methodology has especially proved effective in any discipline that requires carrying a rider, for it supports musculature close to the vertebrae.

So can horse's dance after years of hay high? Absolutely YES!

"Just Dance" coming down the centreline.

Medium NSW State Champion 2012

Medium and Advanced NSW State Champion 2013

"Ecclesbourne" Australian Elementary Champion 2010.

17+hh horse doing tight trot circles in his test. Note his core strength.

"A'seduction" cantering down the centreline.

Multiple State Championships from Preliminary to Grand Prix. Right: Top 5 at the Grand Prix Australian Championship 2010.

"Ausden Kon Tiki" winning Best Managed and Conditioned Horse" Shahzada 2008. Right: 15 hours post 500klm completion, working out for the title.

Hay high is not the answer to all equine woes – but it just might help a few.

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