



Original Research

The Disappearing Lamellae: Implications of New Findings in the Family Equidae Suggest the Loss of Nuchal Ligament Lamellae on C6 and C7 Occurred After Domestication

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ABSTRACT

Conflicting data predominantly describes the equine nuchal ligament lamellae (NLL) attachments as C2–C6 or C2–C7; however, preliminary evidence suggests C2–C5. This study aimed to identify morphological variations in the attachments of the NLL in four species of the family equidae and determine if the variations were species or breed linked. Cadaveric examination evaluated 98 equids; *Equus asinus* (n = 2), *Equus ferus caballus* (n = 93), *Equus przewalskii* (n = 2), and *Equus quagga boehmi* (n = 1). Twenty breeds of *E. f. caballus* were included according to breed type—modern horse (n = 81), ancient type (n = 10), primitive (n = 4). Of the 98 equids, observations were divided into three categories according to the NLL attachments: C2–C5, C2–C6, and C2–C7; in category C2–C7, *E. f. caballus* (n = 3/93), modern horse 0 of 81, ancient 1 of 8, primitive 2 of 4; in category C2–C6, modern horse 2 of 81; in category C2–C5, modern horse 79 of 81, ancient type 7 of 8, primitive 2 of 4. *Equus asinus*, *E. przewalskii*, and *E. q. boehmi* all expressed category C2–C7. In total, 88 of 98 expressed category C2–C5; 2 of 98 category C2–C6; and 8 of 98 category C2–C7. These findings suggest that category C2–C5 provides sufficient evidence to suggest a normal occurrence. The high incidence of an absent NLL on C6 and C7 may be considered a contributing factor in caudal cervical osteoarthritis. Furthermore, category C2–C7 still exists in an ancient and primitive breed closely related to the tarpan, implying the NLL may have been attached from C2 to C7 in prehistoric horse before domestication. This hypothesis is supported by the findings of *E. asinus*, *E. przewalskii*, and *E. q. boehmi*, displaying attachments from C2 to C7.

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1. Introduction

The equine form has captivated the human imagination for over 30,000 years, whether in paleoart, as a likely food source, or in the modern era depicting power, beauty, and prestige [1–5]. Such were the skills of these primitive artists, that their early equine portraits adorning European cave walls, were easily identifiable as tarpan-

and przewalski-like horses—the two dominant equid species that once foraged these regions during the Pleistocene and Holocene Epochs [1,5,6].

However, since these early beginnings, the reliance on artistic skills has been largely superseded by the 1839 invention of the camera, along with its speedy delivery of the photographed image [7]. Yet even after 170 years after invention of the camera, diagrams still dominate educational text, and equine literature providing photographic images depicting normal and/or abnormal anatomy is scarce. Even though one equine anatomic book combined labeled diagrams alongside the cadaveric photograph, it was based on a limited number of dissections dependent on accurate presentation and interpretation of the specimen [8]. Hence, illustrations are still the easiest form of anatomic presentation throughout the world.

A 2014 study reported that artistic license had prevailed through centuries of anatomic text and, more specifically, that in the

Animal welfare/ethical statement: No horses were euthanized for the purpose of this study. Equids were predominantly sourced from abattoirs sent there purposely by the owner. When availability was compromised after death, some specimens were frozen after death.

Conflict of interest statement: The authors declare no conflict of interest.

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modern day equine, current literature was no longer representational of the nuchal ligament lamellae (NLL) [9]. This statement appears quite accurate when comparing various anatomic resources since the 1777 publication of George Stubbs's, "Anatomy of the Horse". In its time, this book was regarded as the consummate guide to equine anatomy for the veterinarian [10]. In addition, it provided a depiction of the NLL attaching from C2 to C7, and since then, equine anatomic text in various languages predominantly represents the NLL in a similar or stylized fashion (Fig. 1). These artistic images provided no information about the cadaver, so the reader was left with the belief that these diagrams were an accurate interpretation of the specimen.

Furthermore, according to a large proportion of anatomic and/or related text, there is a dilemma in the accuracy of the attachments of the NLL. Variabilities in literature describe the equine NLL attaching to the cervical vertebrae from C2 to C7 [10–12,14–25], C2 to C6 [13,26–29], and where it may or may not be absent on C6 [21,28,29]. This is in direct contrast to the 2014 study, where it was reported that the NLL was absent on C6 and C7 in all 35 dissected horses [9]. This would be of concern for biomechanical studies on the equine neck conducted in the live animal, where it was believed that the results were representational of horses with an NLL from either C2–C6 or C2–C7 [30–33].

With this in mind, there have been few studies that describe the prevalence of variations in the NLL neither in the family equidae nor in ancient breed types or primitives in the species *Equus ferus caballus*. Even the previously reported 2014 study noting attachments from C2 to C5 was restricted by its data set to within Australia, coinciding with an over representation of thoroughbreds (51%), and furthermore could not provide evidence of the existence of the NLL on either C6 or C7, as previously cited in numerous studies and literature [9–29]. In fact, correlating further data from the family equidae, with regard to the attachments of the NLL on C6 and C7, may provide an understanding if this reported absence is a recent event through artificial evolution or an anomaly in certain breeds. Consequently, the aim of this study is to identify whether the absence of the NLL is a modern anatomic feature in equine anatomy and, hypothetically, acquired after domestication. If so, it may still exist among genus members within the family equidae.

Therefore, this study intends to investigate the NLL in the family equidae, notably four species: *Equus asinus* (donkey), *E. f. caballus*, *Equus przewalskii*, and *Equus quagga boehmi* (Grant's zebra). Furthermore, *E. f. caballus* will include modern breeds, ancient types, and the primitive. The objective is to build on the 2014 study

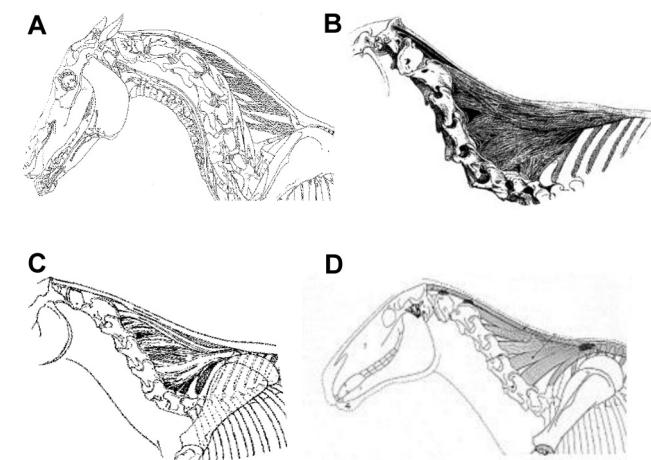


Fig. 1. Diagrams of the nuchal ligament lamellae according to (A) Stubbs, 1777 [10]. (B) Ellenberger, 1899 [11]. (C) Smythe and Goody, 1993 [12]. (D) Goody, 2000 [13].

[9], while providing a better understanding of the NLL, its relationship to the modern day equine and ascertain the biomechanical relevance in current literature.

2. Methods

2.1. Ethical Statement

No equids were euthanized for the purpose of this study, and all observations were obtained after death.

2.2. Animal Details

Dissections were performed on four species of the family equidae ($n = 98$): *E. przewalskii* ($n = 2$), *E. asinus* ($n = 2$), *E. q. boehmi* ($n = 1$), and *E. f. caballus* ($n = 93$). *Equus ferus caballus* included three types: modern ($n = 81$), ancient ($n = 8$), and primitive ($n = 4$). In modern types (recent breeds), there were 14 breeds: thoroughbred ($n = 30$), warmblood ($n = 16$), crossbreed ($n = 8$), Australian stock horse ($n = 6$), standardbred ($n = 5$), quarter horse ($n = 3$), Irish sport horse ($n = 2$), hunter ($n = 2$), Welsh mountain pony ($n = 2$), appaloosa ($n = 2$), hackney ($n = 2$), morgan ($n = 1$), gypsy cob ($n = 1$), and modern type refined Shetland ($n = 1$). In ancient types (old established breeds), there were five breeds: Arabian ($n = 2$), Exmoor ($n = 2$), Fjord ($n = 2$), Icelandic ($n = 1$), and Bosnian mountain horse ($n = 1$). Primitive horses were represented by the Dutch konik ($n = 4$). The equids consisted of 55 males and 43 females, and at the time of death, they were aged between stillborn (9.5 months in utero premature) and 30+ years.

2.3. Anatomic Identification

The equine nuchal ligament is comprised of two distinct portions with a left and right side.

1. The funicular cord, arising from the external occipital protuberance and inserting into the summits of the thoracic dorsal spines at the wither.
2. The lamellae portion, which are elastic fibers forming into digitations arising from the second and third thoracic dorsal spines and funicular cord. At which point, the fibers advance ventrally and cranially, ending on the dorsal spines of the cervical vertebrae from C2 to C6, or C2 to C7 [2,15,21].

2.4. Dissections

With the equid lying in a left or right lateral recumbency, the integument is removed on the exposed side from the occiput and mandibular ramus along the median plane of the ventral and dorsal neck. The skinning procedure continues caudally with removal of the mane occurring simultaneously. Continue removing the integument along the median plane until it meets the manubrium of the sternum on the ventral aspect and dorsally traverses beyond the thoracic dorsal spines at the wither, until the girth line is reached, while remaining at the level of the elbow joint distally (Fig. 2). The removal of the integument will incorporate the cutaneous omo-brachialis and sufficient cutaneous trunci to reveal the required region.

Proceed with caution when resecting the epaxial neck muscles that attach to the nuchal ligament funicular cord and NLL; the fibres of each structure blend intimately together, making resection difficult, which in turn may comprise the integrity of the structures under review. This resection reveals the attachments of the nuchal ligament funicular cord to the external occipital protuberance and

thoracic dorsal spines at the wither and the attachments of the NLL to its associative cervical vertebrae and thoracic dorsal spines. At this point, the individual muscles will be resected along their length incorporating all attachments.

With the lateral neck and shoulder musculature exposed, resect the brachiocephalicus and trapezius cervicis et thoracis. The complete forelimb is then resected as one entity by disconnecting the scapular and humerus from the extrinsic muscle attachments that connect the forelimb to the thorax; this reveals the lateral muscles of the thorax and pectoral group. Next, resect the latissimus dorsi, rhomboideus cervicis et thoracis, subclavius, and serratus ventralis cervicis. Then serratus dorsalis cranialis, splenius, iliocostalis, and the cervical and cranial portion of longissimus dorsi to T5. The semispinalis capitis is now exposed on removal and rectus capitis dorsalis major et minor, the nuchal ligament funicular cord, is revealed at the external occipital protuberance. A large portion of the NLL is also now exposed, but not the attachments to the cervical vertebrae.

Resect the obliquus capitis cranialis et caudalis; then with delicate precision, resect multifidus cervicis et thoracis from C2 to T5; these are intersegmental bundled muscles and from C2 to C4 are the closest in proximity to the cervical attachments of the NLL. At C4, this proximity to the NLL is replaced by the spinalis dorsi muscle that attaches to the lateral aspect of the cervical and thoracic dorsal spines. The resection is now dependant on whether the NLL is attached to C6 and C7, or not. In the former, the spinalis dorsi is resected from the lateral aspect of the cervical dorsal spines and the digitations of the NLL. In the latter, the spinalis dorsi is resected from the lateral aspect of the cervical dorsal spines only. In both, the resection remains continuous along the thoracic dorsal spines until the fifth.

When there are no attachments, the spinalis dorsi muscle is removed from C4 to C5 immediately lateral to the NLL; however, this is not so on C6 and C7, as the resection reveals a loose fascial membrane on the midline that separates the left and right spinalis dorsi muscles. After which, resection remains continuous along the dorsal spines of the thoracic vertebrae until the fifth.

When there are NLL attachments on C6 and C7, resect the spinalis dorsi muscle from C4 to C5; the muscle attachments to the NLL become apparent and must be carefully resected to reveal the extent of this strong connection between the muscle and ligament.

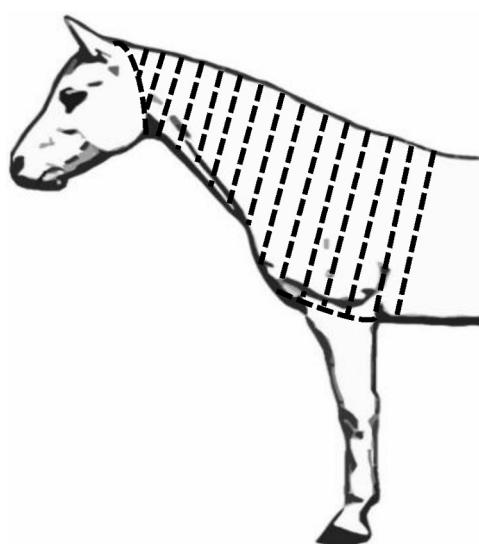


Fig. 2. The area of integument removal—left side.

Once the disconnection of the spinalis dorsi muscle from the NLL has been accomplished, continue the resection along the thoracic dorsal spines until the fifth.

Of special note, the spinalis dorsi muscle is the closest to the median plane to be resected that reveals the NLL at the level of C5–C7.

After dissection, members of the family equidae were distributed according to the presence or absence of the NLL from C2 to C5, C2 to C6, and C2 to C7, determined by the anatomic description in Section 2.3.

3. Results

Of the 98 dissected members from the family equidae, 8 of 98 (8.2%) presented with NLL attachments from C2 to C7, 2 of 98 (2%) presented with NLL attachments from C2 to C6, and 88 of 98 (90%) presented with NLL attachments from C2 to C5 (Table 1).

3.1. *Equus ferus caballus*

Of the 14 modern breeds represented by 81 horses in *E. f. caballus*, all 81 of 81 (100%) presented with no NLL attachments on both C6 and C7 (Fig. 3), and 2 of 81 (2%) presented with NLL attachments on C6 only.

Of the five ancient breeds represented by eight horses in *E. f. caballus*, 7 of 8 (88%) presented with no NLL attachments on C7, and 1 of 8 (1.2%) presented with NLL attachments on C6 and C7 (Fig. 4A).

Of the one primitive breed represented by four Dutch konik horses in *E. f. caballus*, 2 of 4 (50%) presented with no NLL attachments on C6 and C7, and 2 of 4 (50%) presented with NLL attachments on C6 and C7 (Fig. 4B).

3.2. *Equus przewalskii*, *Equus quagga boehmi*, and *Equus asinus*

In 2 of 2 *E. przewalskii* (100%), 2 of 2 *E. asinus* (100%) and 1 of 1 *E. q. boehmi* (100%) presented with NLL attachments on C6 and C7 (Fig. 5).

3.3. Digitation

In all 98 equids, the digitation of the NLL began at C2 and thereafter remained in sequence on the dorsal spines of the cervical vertebrae until attaching to C5, or C5 and C6, or C5, C6, and C7.

In *E. f. caballus*, the digitation was obvious and variable in shape and size between horses with no breed or gender specificity. In the Dutch konik and Bosnian mountain horse, digitation was apparent with the attachments to C6 and C7, displaying obvious separation of the elastic fibers.

In *E. przewalskii* and *E. q. boehmi*, the digitation was obvious with the attachments to C6 and C7, displaying strong cord bands of bundled fibers. In *E. asinus*, the densities of the elastic fibers and digitations were the most notable among the equids in this study. The digitations between the cervical vertebrae were minimal in appearance, and the NLL appeared as a flat sheet of elastic fibers attached from C2 to C7 (Fig. 6).

3.4. *Spinalis dorsi*

Of special note was the attachment of the spinalis dorsi muscle to those fibers of the NLL attaching to C6 and C7. The attachment between the NLL and spinalis dorsi muscle displayed a very strong connective bond along the digitation of the NLL until the dorsal edge of the spinalis dorsi muscle was reached; it was bilateral in presentation and attached to no other structures except the cervical vertebrae. This is a new finding in equine anatomy (Fig. 7).

Table 1

Observations of the attachment points of the nuchal ligament lamellae (NLL) in 98 horses of mixed gender and identifiable breeding aged between 9.5 months stillborn and 30+ years.

Breed	n	Gender Male/Female	C2–C7	C2–C6	C2–C5
Thoroughbred	30	20 M/10 F		30	
Warmblood	16	8 M/8 F		1 ^a	15
Crossbred	8	6 M/2 F			8
Aust. Stock Horse	6	6 M		1 ^{a,b}	5
Standardbred	5	5 F			5
Quarter Horse	3	3 F			3
Irish Sport Horse	2	1 M/1 F			2
Hunter	2	1 M/1 F			2
Welsh Mt. Pony	2	2 M			2
Appaloosa	2	2 F			2
Hackney	2	1 M/1 F			2
Morgan	1	1 F			1
Gypsy Cob	1	1 M			1
Shetland	1	1 M			1
Arabian	2	2 F			2
Fjord	2	1 M/1 F			2
Exmoor	2	2 F			2
Icelandic	1	1 M			1
Bosnian Mt. Horse	1	1 F	1 ^a		
Dutch Konik	4	2 M/2 F	2 ^a (1 M/1 F)		2
<i>Equus przewalskii</i>	2	2 M	2 ^a		
<i>Equus asinus</i>	2	2 M	2 ^a		
<i>Equus quagga boehmi</i>	1	1 F	1 ^a		
Total	98	55 M/43 F	8 ^a	2 ^a	88

Abbreviation: Mt., mountain.

^a Indicates attachment of spinalis dorsi muscle to the NLL.

^b Indicates NLL absence on T1.

4. Discussion

This study describes the morphological variations of the NLL in four species of equidae and further supports the earlier 2014 findings in modern horse breeds. In addition, it explains the different morphological types of NLL in previously unreported *E. asinus*, *E. przewalskii*, and *E. q. boehmi* and includes 20 breeds of *E. f. caballus*, thus providing a broader scope of data than the previous study.

The present study found that NLL attachments from C2 to C7 existed in *E. asinus*, *E. przewalskii*, *E. q. boehmi*, and two primitives and one ancient type horse in *E. f. caballus*. It further reported that the NLL attachments from C2 to C5 dominated the results in the modern horse (81 of 81). Even so, two breeds of *E. f. caballus*,

namely the Dutch konik and Bosnian mountain horse (a primitive and ancient breed, respectively), still provided evidence that the NLL attached from C2 to C7 [34,35]. According to literature, the Dutch konik and Bosnian mountain horses are descendants of the now-extinct tarpan (*Equus ferus gmelini*), a wild horse of Europe believed to be seen in cave paintings alongside *E. przewalskii* [1,5,34,35]. There is also some consensus that the tarpan is the main ancestor of the present day modern type, and phenotypically, the Dutch konik is considered “true” to the tarpan type [34,36,37]. However, there appears a discrepancy as to which tarpan is the forefather—the steppe tarpan (South Russia) or the forest tarpan (northern part of east and west Europe) [34,36].

The earliest evidence for equine domestication appeared after 4800 BCE on the Eurasian steppes and thereafter, the remnants of wild horses were hunted into areas less habitable by man [34,36]. Since domestication, the difficulty in a strict descriptive phenotype from scholars dating before 1900 appears in the observation of wild herds presumed to be tarpans that were in fact mixed with domestic ferals [34–38]. However, the wild forest horses of Bialowiez Forest (Poland) or forest tarpans were eventually captured and domesticated in the late 1700s [34]. One hundred fifty years later through a convoluted process of rediscovery, tarpan-like horses were reconstructed through specialized breeding programs and became known as the konik [34,36]. It is from these origins that the Dutch koniks seen in this study presented with the NLL attachments from C2 to C7 and the unique splint bone asymmetry that may be an adaptive response to forest living [39]. In addition, the Bosnian mountain horse is a breed that morphologically resembles the konik, which is logical when considering their singular ancestry [35,40]. Consequently, as both are known descendants of the tarpan and were the only *E. f. caballus* to produce attachments of the NLL from C2 to C7 in this study, it would be plausible to assume that it was a heritable trait from the tarpan.

To understand this association further, it is important to look at phylogenetic relationships [41,42]. Members of the family equidae have a common prehistoric ancestor and are a prime example of homologous evolution; they are of the order perissodactyla, nonruminant hooved mammals that incorporate rhinocerotidae and tapiridae [41,42]. As a distant relative to equidae, the Malayan tapir or *Tapirus indicus* is reported to be a forest-dwelling “living fossil” with an NLL attached from C2 to C7 [42,43]. They share a common ancestor with equidae from over 60 million years ago—*Hyracotherium* [41]. After diverging some 54 million years ago (Mya), hippomorphs eventually emerged with the only extant genus, *Equus* some 3.8 Mya [42]. *Equus asinus* (donkey) diverged from its common ancestor with the caballine horses 2.1 Mya, *Equus quagga* (the zebras) 1.2–1.6 Mya, and *E. przewalskii* 50,000 years ago [42]. At this point, all these ancestral relationships between individual extant *Equus* members have been dissected for this study, except the *T. indicus*, where the findings were reported in an 1871 study [43]; in each instance, they all presented with NLL attachments from C2 to C7.

This provides a plausible timeline of when the NLL began to alter in *Equus*; however, proving NLL morphologically in the tarpan before domestication is difficult without accessing suitable cervical specimens to look for specific enthesis patterns. However, it is plausible to consider that it did exist before domestication via its descendants—the Dutch konik and Bosnian mountain horse—the only two breeds in this study representative of a strong and close tarpan descent. Logic dictates that as it is present in its descendants and in three related *Equus* genera (donkey, zebra, and przewalski) plus distant relatives in the Tapir and that all *Equus* descended from the same lineage; then the likelihood that the tarpan had an NLL from C2 to C7 before domestication is highly probable.

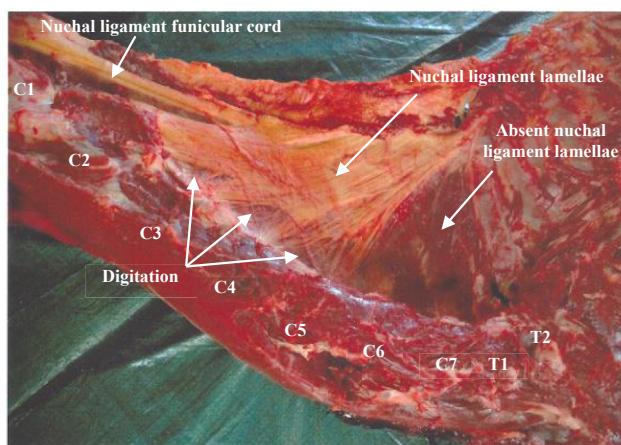


Fig. 3. The nuchal ligament lamellae from C2 to C5 in a 5-year-old male Irish sport horse.

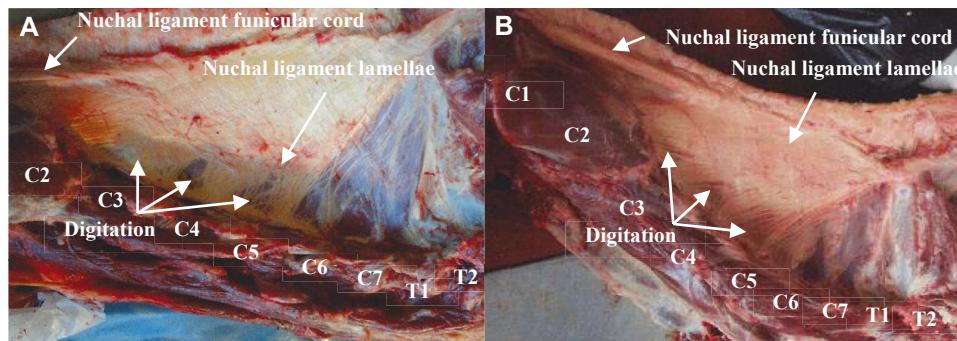


Fig. 4. The nuchal ligament lamellae in the (A) Bosnian mountain horse and (B) Dutch konik.

The possible explanation as to why other ancient types did not have the NLL from C2 to C7 is because they have been separated from their origins for thousands of years and had some form of manipulative or artificial breeding programs involved in modern day specimens. Historians have various opinions about the purity of each breed, but in general, do agree in the timeframes they have been associated with man in various capacities [40,44,45]. Ancient breeds used in this study with known history were as follows: Arabian 3–4,000 years, Fjord 3–4,000 years, Exmoor 1,100 years, and Icelandic 1,000 years [40,44,45]. Whereas, the Dutch konik was established from the wild forest horses (forest tarpans) in Poland in the last 200 years, and the same timeframe virtually exists for the Bosnian mountain horse, that in its current breeding program eliminated outcrosses, so as to re-establish the purebred from wild mountain stock [34,35].

In combining the results of the 2014 study and this present study, the total modern breeds investigated equated to 17, totaling 116 horses; the presence of the NLL from C2 to C7 was 0 of 116 (0%); the presence of the NLL from C2 to C6 was 2 of 116 (1.7%) [9]. The combined studies further support the hypothesis that the NLL are no longer functional on C6 and C7 in the modern horse.

As domestication is the possible cause leading to the absence of NLL on C6 and C7, the ramifications are very likely instable in the caudal neck; this would explain why the caudal cervical vertebrae exhibit overall, the greatest range of motion in the equine neck [30,32]. Findings from a preliminary modeling study of the equine cervical spine suggested that lateral bending was greatest at C7–T1; axial rotation was second and third highest at C6–C7 and C7–T1, respectively [31]; and flexion/extension was uppermost at C1 and C6 [30]. It could be postulated that these results are due to the absence of the NLL on C6 and C7, where in principle, its role is to support and stabilize the neck [18,28]. Hence, without the supportive and stabilizing structures provided by the NLL, the range of motion previously reported in C6 and C7 could be in fact a direct correlation to the absence of the NLL [9].

Furthermore, equine anatomic studies have reported a common occurrence of osteoarthritis in the caudal cervical articular process joints (APJs) in horses of any breed older than 4–5 years [46,47]. This osteoarthritis of the APJs, located dorsally along the vertebral column, occurs primarily at C6 and C7 [47]; whereas osteoarthritis has also been identified in the APJs between C5 and C6 [48]. Dyson [49] mentions that in normal horses, finding osteoarthritis changes in the APJs from cranium to C5 is relatively rare. These studies concurred that there was no association between osteoarthritis of APJs and gender, breed, or usage, but agreed that a positive correlation to osteoarthritis in APJs existed with the increase in age [48,50]. In addition, horses afflicted with this condition may present with clinical lameness or unexplained poor performances [46–51].

The consequences can be considered from two points: firstly, the absence of NLL provides no supportive function on C6 and C7, and secondly, the spinalis dorsi muscles attach to the NLL when it is present on C6 and C7; its anchorage to the dorsal spines of the thoracic vertebrae provides further support to the caudal neck, which would suggest that its presence could limit excessive hypermobility. Although the influence of the equine NLL on neck stiffness may differ from its influence on the range of motion [52], in human literature, hypermobility has been linked to predispose the joint to premature development of degenerative joint disease [53]. This would correspond to the reported osteoarthritis in the caudal cervical APJs that are age induced [46–49]; even though the horses reported in these studies were modern domestics, it therefore stands to reason that this degenerative condition appears concurrently with the absence of NLL on C6 and C7.

One final consideration is that associated with future studies and correctional pathways in anatomic literature. As this study confirms the absence of the NLL on both C6 and C7 in modern type horses, additional studies exploring the biomechanics of the equine neck with accurate anatomic depiction would be a beneficial tool in devising supportive mechanisms that could aid training and riding

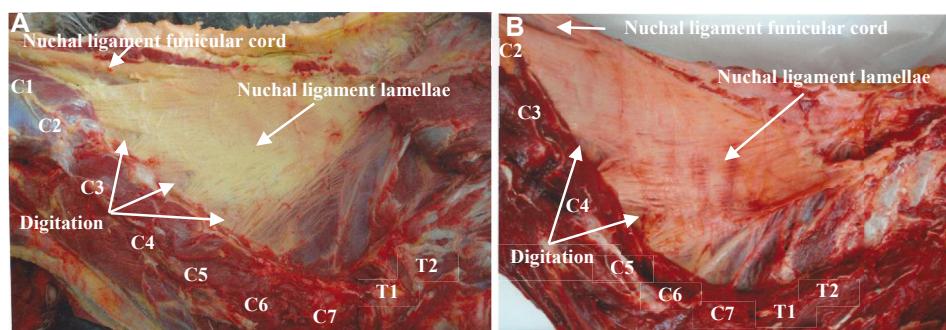


Fig. 5. The nuchal ligament lamellae with obvious digitation and strong chord-like attachment to C6 and C7. (A) *Equus przewalskii*. (B) *Equus quagga boehmi*.

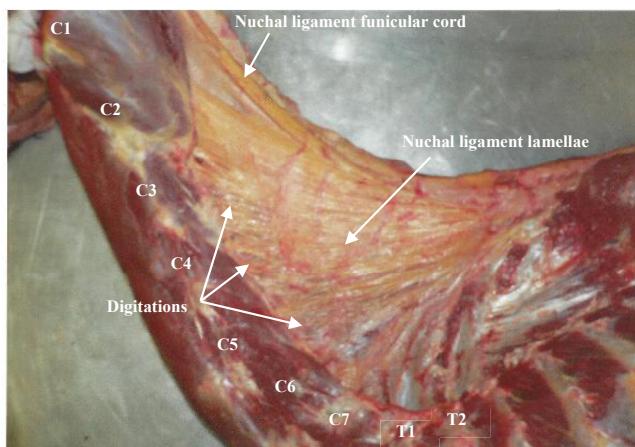


Fig. 6. The nuchal ligament lamellae in *Equus asinus* with minimal digitation in the lamellae.

disciplines. In effect, such mechanisms may even be beneficial in averting early onset of arthritic APJs in the caudal neck as previously described [46–51]. Furthermore, it would be advantageous if anatomic and related equine text disseminated these findings in forthcoming publications as a point of correctness, thus avoiding confusion in the literature while providing an accurate understanding of those structures under load.

5. Conclusion

The findings in this study have shown that the NLL predominantly attaches from C2 to C5 in the modern horse, with the evidence suggesting that this is a normal occurrence. Furthermore, the absence of NLL on C6 and C7 may be a contributing factor when investigating the etiology of caudal cervical osteoarthritis. Finally, the presence of the NLL attaching from C2 to C7 in tarpan-related descendants and *E. asinus*, *E. przewalskii*, and *E. q. boehmi* suggests that the NLL could have been present in prehistoric horse before domestication and that its absence is in direct correlation to domestication in the modern horse.

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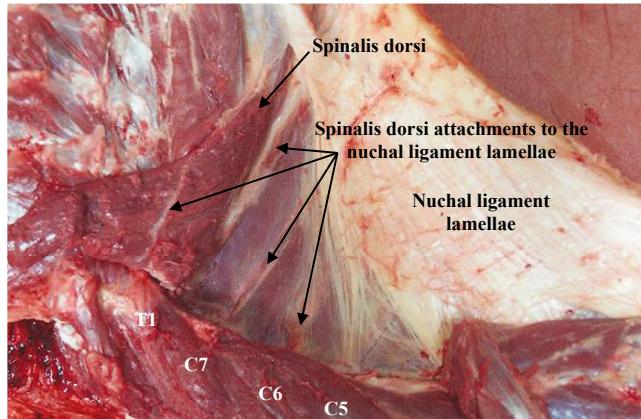


Fig. 7. The attachment of the spinalis dorsi muscle (still in situ) to the C6 and C7 nuchal ligament lamellae digitations in a Dutch konik.

organizing the Dutch konik horses and distal limbs; Kristen Braeber, Hortobagy National Park, Hungary, for her assistance with przewalski horses; Wildlands Zoo for their assistance in a Grant's zebra, Emmen, the Netherlands; Anton Dolinšek from Planibo Bosnian mountain horse stud, Slovenia, for his assistance in this study; Equine Studies, the Netherlands for logistical assistance and resources; the Australian College of Equine Podiotherapy for the use of its facilities; to those authors/editors/publishers of those articles, journals, and books cited in this article.

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