Open Journal of Veterinary Medicine, 2024, 14, 229-256
https://www.scirp.org/journal/ojvm
ISSN Online: 2165-3364
ISSN Print: 2165-3356

Canine Myofascial Kinetic Lines: A Descriptive Dissection Study Including Related Function and Locomotion and Comparison of the Human and Equine Myofascial Kinetic Lines

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How to cite this paper: Elbrønd, V.S. (2024) Canine Myofascial Kinetic Lines: A Descriptive Dissection Study Including Related Function and Locomotion and Comparison of the Human and Equine Myofascial Kinetic Lines. *Open Journal of Veterinary Medicine*, **14**, 229-256.
https://doi.org/10.4236/ojvm.2024.149017

Received: July 18, 2024
Accepted: September 16, 2024
Published: September 19, 2024

Abstract

Aim: This dissection study was conducted to verify if the Myofascial kinetic lines, outlined in detail in humans and recently documented in horses, were present in dogs. These dynamic lines present rows of interconnected muscles, myofascia and other fascia structures, which influence the biomechanics of the spine and limbs. **Methods:** Forty-two dogs of different breeds and genders were dissected, imaged, and videoed. **Results:** Similar kinetic lines were verified in the dog, as described in humans and horses, and additionally, three new branches of the lines were discovered. The kinetic lines described were three superficial lines: Dorsal, Ventral, and Lateral, which all started in the hindlimb and ended in the temporal and occipital regions. These lines act respectively in spinal extension, flexion, and lateral flexion. Three profound lines, which started in the tail and ended in the head. The Deep Dorsal Line followed the transversospinal myofascia. The Deep Ventral Line showed an additional start deep in the medial hind limb, continued in the hypaxial myofascia, and enveloped all the viscera. Also, the Deep Lateral Line started in the hindlimb but parted along the trunk in the deep lateral myofascial structures. Two helical lines crossed the midline two or three times and served to rotate the spine. The Functional Line established a sling from the axilla to the contralateral stifle and presented a new ipsilateral branch. The Spiral Line connected the head and the ipsilateral tarsus and additionally presented a new straight branch. The four front limb lines describe their motion: the Front Limb Protraction and Retraction, Adduction, and Abduction Lines. **Conclusion:** The canine lines mirrored the equine and human lines with exceptions due to differences in anatomy, foot posture, lumbosacral flexibility, and their biomechanical constitution as predator versus prey animals. Additionally, three new canine branches were verified and described.

Keywords

Myofascial Kinetic Lines, Canis Familiaris, Superficial Lines, Deep Lines, Locomotive Connections, Viscero-Somatic Connections

1. Introduction

Up to now, only a few research studies on the canine locomotion system have involved the 3-Dimensional fascia network as an influencer on biomechanics.

The myofascial kinetic lines, which comprise interacting myofascial structures, present a 3-Dimensional fascia network through the whole body and have so far only been accepted, verified, and isolated in humans [1] with ten lines and horses [2] [3] with eleven lines. They have yet to be isolated and verified in canines.

These lines span from the head to the hind limbs and from the trunk through the front limb lines. They play a role in supporting and balancing the whole body in terms of posture and motion. They also describe the motions around the spine in terms of flexion/extension, lateral flexion and rotation.

The lines have been dissected following specific rules by [1] based on the myofascial expansions, the direction of the force through the lines, and the body level of the lines.

The lines constitute myofascia and muscles spanning over several joints, and only a few exceptions of bony connections are present, as seen in the human superficial front line in which a large bony connection is seen as a gap between the rectus femoris and the rectus abdominis muscle. The similar line in the horse does not have bony connections; therefore, it follows the rules more strictly. The differences most likely reflect the body posture of bipeds versus quadrupeds.

The equine lines are as follows: The Superficial Dorsal Line (SDL) and the Deep Dorsal Line (DDL) both promoting spinal extension, the Superficial Ventral Line (SVL) and Deep Ventral Line (DVL) contributing to spinal flexion, the Superficial and Deep Lateral Line (SLL, DLL) working in lateral flexion, the Functional Line (FL) and the Spiral Line (SL) important for spinal rotation as well as the Front Limb Lines acting in pro- and retraction together with add- and abduction. The present study aims to investigate whether similar lines can be dissected, described, and isolated in the dog.

The anatomy of the locomotion system in the horse and the dog, both of which are quadrupeds, is basically identical, although specific and significant differences are presented in early and basic biomechanical studies [4]-[6]. Some of the major differences are present in the extremities, e.g., in the foot, digitigrade versus unguligrade, the angles of the joints, and in the lumbosacral region [4] [5] [7], reflecting their role as predator versus prey animals.

The equine and human myofascial kinetic lines have been found to connect and fulfil the pattern of the basic body skeleton established by the fascia network, which outlines the whole body.

Myofascial kinetic lines originate in macroscopically identifiable and dissectible myofascial expansions based on the embryological development of the myofascial system in mammals. "Soft tissue", including muscles and fascia/connective tissue, derives from the mesodermal layer and the primitive connective tissue (the mesenchyme), which initially create the soft tissue skeleton of the embryo. During embryo development, muscles, and other cell types, such as bone and parenchymal cells, differentiate and grow into the mesenchyme [8] [9]. Thus, close connections between muscles and fasciae are established and develop further postnatally into a delicate interwoven full-body network.

In the mature animal, myofascial connections are recognized at the micro- and macroscopical levels as the endo-, peri-, and epimysium, as well as structures such as tendons, ligaments, and myofascial expansions [9]-[11]. Biomechanically, the myofascial interactions are involved in direct muscle force transmission models and parallel muscle force transmission and into myofascial expansions, where muscle force is transferred parallel in the endo-, peri-, and epimysium, reaching the periphery of the muscle and further distributed onto neighbouring muscles and fascia structures [12].

Researchers [12]-[14] have measured that this parallel transfer (myofascial expansion) affects muscle interactions in such a way that up to 30% of the total muscle force can be transmitted into another structure or muscle via a myofascial expansion. These results challenge the general perception of muscle function, suggesting that muscle force transmission is more complex than traditionally understood. It supports the idea that muscle force can be transmitted in multiple pathways into neighbouring structures, thereby extending force over shorter or longer distances. It opens the possibility of approaching muscle force transmission as a much more complicated action than observed in traditional and well-known direct transmission.

The presence of tension in myofascial structures is integral for the development and strengthening of them, following the principle of supply and demand [15] [16].

Dissection studies were undertaken to address the following hypotheses:

1) It is possible to identify, dissect, and give a detailed anatomical description in dogs of the same eleven kinetic myofascial lines already published for horses and the ten lines found in humans.

2) Differences in the lines exist between dogs and horses due to their biomechanical constitution, roles as predator versus prey, and their evolution in terms of the foot and toe(s) - unguicula (dog) versus ungula (horse).

3) Differences between the canine, equine, and human lines exist due to the posture of quadrupeds versus bipeds and the presence of a functional tail.

2. Material and Methods

2.1. Background and Planning

After having dissected and described the Equine Myofascial Kinetic Lines and further successfully used them clinically for evaluation of locomotion and as a diagnostic tool, it became urgent to continue with dissections of dogs to gain the same benefits. Equine and canine anatomy was thoroughly compared using different anatomical literature and atlases, the possible anatomy of the dog lines was noted, and a working and guidance plan was made.

2.2. Animals

The dogs were euthanized due to conditions not related to this study, and euthanization was performed by private practicing veterinarians, after which the cadavers were donated to the Section of Pathobiological Sciences, University of Copenhagen, for dissection and research purposes. The specific history of each dog was unknown to the author.

Full ethical approval was gained from Copenhagen University, Dept. for Veterinary and Animal Sciences (IVH), Faculty of Health & Medical Sciences before the start of the trial (protocol ID 2018-15-0201-01462).

For the dissections, thirty-eight intact cadavers and extremities from two dogs were used, and full lines or partial lines were dissected. To evaluate the third dimension in relation to the muscles and the viscera as well as the fascia layers, two dogs were frozen (one hanging and one lying prone), and segmental transverse sections were subsequently cut.

2.3. Dissections

2.3.1. Dissection Rules and Performances

The lines were dissected using direct as well as blunt dissection techniques and followed the rules presented in [1] and as performed in Elbrønd & Schultz [2] [3]. These rules included that the myofascial structures were to be arranged at the same functional direction, that they followed the direction of tension (lines of tension), that they were to be situated at the same body level, and that they spanned over several joints. The integration of the structures was additionally tested interactively to confirm a physical (tension lines) and functional connection between the structures. The lines were isolated, still attaching to the skeleton, and later isolated and extracted as one piece from the rest of the cadaver.

To use the cadavers as optimal as possible, the major plans were presented below:

Superficial lines were dissected first hand on both sides and, hereafter, the profound lines. This was performed in 22 dogs. When dissecting the helical lines, care was taken not to disrupt the crossing-overs in the dorsal and ventral midlines, giving the possibility of dissecting the full lines in the same cadaver. This was done in 16 cadavers. Front limb lines were dissected in 10 cadavers and 4 isolated front limb specimens. Additionally, and whenever possible, the cadavers were used for local dissections to check-up and confirm specific connections and structures, e.g., the ipsilateral branch of the FL.

2.3.2. Documentation

Photographs were taken using a Canon G1max, a GX200 Ricoh, a Fuji X-T1 camera, and a Samsung 7 + 5G tablet. Working videos were recorded on the Canon

G1max camera and Samsung 7 + 5G tablet. Adobe photoshop version CS4 extended was used to edit the images for the publication.

The nomenclature chosen for the dog myofascial kinetic lines was similar to that used for the equine lines, based on the Veterinary Nomina Anatomica, and reflects the posture and anatomical planes of domestic animals.

The dissected myofascial kinetic lines were present on both the right and the left side of the body. Moreover, the DVL was approached as a right and a left part even if the line was found to be a 3-D unit and difficult to separate, since besides the locomotion muscles, it also includes the viscera in the thorax and abdomen. (Table 1)

Table 1. Overview of the eleven Canine Myofascial Kinetic Lines.

Lines abbreviations	Lines full name
SDL	Superficial Dorsal Line
DDL	Deep Dorsal Line
SVL	Superficial Ventral Line
DVL	Deep Ventral Line
LL, superficial and deep	Lateral Line, superficial and deep
FL	Functional Line
SL	Spiral Line
FLPL	Front Limb Protraction Line
FLRL	Front Limb Retraction Line
FADL	Front Limb Adduction Line
FABL	Front Limb Abduction Line

3. Results

3.1. General Observations

The constitution and thickness of the fascia differed between the dog breeds and sizes. Smaller dogs exhibited very thin and very flexible fascia, making it difficult to see the isolated collagen fibre bundles and determine the direction of the fibres and lines of tension. Photo and video recordings, interactive dissection methods, and the use of scattered light at different angles helped to resolve this issue, presenting fibres in a clearer and more discernible fashion. In larger and highly muscled dogs, the fasciae were thicker and denser, and the collagen fibres were clear and identifiable.

3.2. Dissections

Superficial Dorsal Line, SDL

The SDL started in the plantar region of the *Phalanx media* and *proximalis* of Phalanx II-V. From here, the line progressed with the four flexor tendons/subtendons on the plantar surface of the *Metatarsus,* where the tendons fused and

Figure 1. (a)-(d) illustrate five superficial and one deep myofascial kinetic line painted on a dog (Figure 1(a) and Figure 1(c)), and details from dissections (Figure 1(b), Figure 1(d) and Figure 1(e)). In Figure 1(a), the full progress of the Superficial Dorsal Line (SDL, green), the Superficial (S) and Profound (P) Lateral Line (LL, orange), the Front Limb Protraction Line (FLPL, yellow) and the Front Limb Retraction Line (FLRL, pink) are illustrated. In Figure 1(b), the SDL is dissected in the *Regio poplitea*. Myofascial expansions (white ovals) reach from the *M. biceps femoris* and *M. semitendinosus* to the *M. gastrocnemius*. In the mid part of the expansion, the hind limb sling of the SDL is present. The sling reaches the dorsum of the Tibia, where the two parts fuse (not illustrated). Figure 1(d) presents the erector spinae muscles of the canine lumbar region. Notice the size of the *M. iliocostalis,* which, compared to the horse, is significantly larger and, in collaboration with the *M. long. lumborum* influences the balance of the pelvis and the SDL. In Figure 1(c), the Superficial Ventral Line (SVL, blue) is painted on the dog, and the major myofascial structures are dissected and isolated as a long and continuous line (Figure 1(e)).

approached the *Tuber calcanei*. It then capped over the *Bursa calcanei* and transitioned into the *Tendo calcaneus* and established contact with the *Musculus* (*M.*)

gastrocnemius, *caput medialis and lateralis* (and *M. soleus*) (**Figure 1(a)** and **Figure 1(b)**). Proximally, in the *Regio poplitei*, the myofascia of the gastrocnemius heads expanded laterally into the most distal aponeurotic part of the *M. biceps femoris* and medially to the tendinous part of the *M. semitendinosus*. Alongside these muscles, multiple fibrous intermuscular connections (myofascial expansions) were observed.

The line was parted in two along the caudal side of the thigh and towards the *Tuber ischiadicum*. The *M. biceps femoris*, laterally, and *M. semitendinosus*, medially and in proximal direction, a myofascial attachment to the fibrous *Ligamentum* (Lig.) *sacrotuberale* (**Figure 2(b)**) was observed. Continuing along this structure, it connected into the tight fibrous fascia layer in the *Regio sacralis et lumbosacralis* and onwards into the paravertebral erector spinae muscle complex (**Figure 1(d)** and **Figure 2(b)**, **Figure 2(e)**), (*M. longissimus pars lumborum*, *thoracis*, *cervicis*, *atlantis*, *et capitis*) and the *M. iliocostalis*, which was included via the *Tendo Bogorodsky*. The two complexes extended the line from the pelvis to the *Atlas* and the *Os temporalis*, *Processus mastoideus*. The myofascial expansions from the *M. longus capitis* proceeded into the *M. temporalis*, which continued in the oral direction over the dorsal part of the *Margo orbitalis* and caudomedially into the *Orbita* along the Paries dorsalis. In this span, a multitude of fibrous connections were observed attaching to the dorsum of the *Periorbita*. The temporal myofascia continued towards the offspring of the *Nervus opticus* over the *Foramen opticus* and in a medial direction to the Orbital part of the *Os frontale* and the lateral wings of the *Os sphenoidale*. The lateral part of the temporal myofascia passed in a ventral direction over the *Articulatio temporomandibularis* and connected beneath the *Arcus zygomaticus* to the *M.* masseter.

A canine expansion of the SDL, a hindlimb flexion sling enclosing the stifle from both lateral and medial sides, was discovered (**Figure 1(a)**, **Figure 1(b)**). It extended from the region of the *Tuber ischiadicus* to the distal part of the *Tuberositas tibia*, distal to the stifle. This sling included two major propulsion muscles, the biceps femoris muscle, establishing the lateral side of the sling, and medially the cranioventral continuation of the semitendinosus muscle. Both muscles end in an aponeurotic and tendinous part, which fuse together and dorsally connect on the *Tibia* close to the distal part of the *Lig. patellae*.

Function: The function of the structures taking part in the SDL indicates that the line is engaged in movements such as Extension of the head, neck, thorax, lumbar and sacral regions, extension of the pelvis, and propulsion of the hindlimb with an extension of the hip joint, flexion of the stifle, flexion of the hock and flexion of the toes. The hindlimb flexion sling can pull the distal part of the hindlimb proximally, shortening the limb's functional length/lever and enhancing the ability to lower and stabilize the trunk. Additionally, it shortens the stride length, which can increase the acceleration initially. The latero-lateral position of the sling's structures also supports and stabilizes the stifle during the "short-legged" propulsion.

Superficial Ventral Line, SVL

The SVL (**Figure 1(c)**, **Figure 1(e)**) initiated at the insertions of the *M. extensor digitorum longus* dorsally at the *Phalanx distalis* II-V. It traveled along the dorsal surface of the hindlimb via the extensor muscle to the *Margo cranialis tibia*, merged into the profound layers of the proximal *Fascia cruris,* and then into the *Lig. patellae* continuing into the *M. rectus femoris of M. quadriceps femoris*. The *SVL* progressed in a cranio-proximal direction into the *Fascia femoralis*, which outlined the *Canalis femoralis*. From here, the line extended into the *Lig. inguinalis* and the *Tendo prepubicus*, *reaching* the *M. rectus abdominis* and the most caudal part of the *Vagina musculus rectus abdominis*. Moving cranially, it followed the *M. rectus abdominus* (**Figure 2(e)**), proceeded into the deep fascia layer, *Fascia pectoralis* on the ventral thorax wall, and extended to the tiny *M. rectus thoracis* over the cranial part of the sternum to the *M. sternocephalicus pars mastoideus* and *occipitalis* originating respectively from the *Processus mastoideus* (*Os temporalis*) and the *Crista nuchalis* (*Os occipitalis*). The sternocephalic myofascia expanded into the *Fascia parotis* at the horizontal level of *Angulus mandibularis*, covering the *Gl. parotis* and *Mandibula*, merging rostrally into the *M. masseter*. Additionally, the masseter muscle was found to attach and expand not only to the *Arcus zygomaticus* but also to the *M. temporalis* (in a dorsomedial direction), the Periorbita, and the *M. pterygoideus lateralis*.

Function: The function of the structures in the SVL indicates that the line is involved in flexion of the head, neck, thorax, lumbar and sacral regions, flexion of the pelvis, protraction of the hindlimb with flexion of the hip joint, extension of the stifle, the hock and the toes. The SVL in the hindlimb is, like the SDL, able to shorten the functional length of the limb in the protraction phase by flexing the stifle and using the bony attachment of the patella ligament as the distal point during protraction.

Lateral Line, LL

The LL was found to be subdivided into a superficial and a deep part.

Both parts of the lateral line had a common start at the insertion of the *Tendo musculus flexor digitorum lateralis*/the *M. peroneus longus* on the dorsolateral aspect of the hindlimb. The line passed in a proximal direction over the tarsal joint, where it was embraced and supported by the *Retinaculum extensorum*. In the lateral *Regio cruris* the line continued in a proximal direction in the space between the digital flexor and extensor compartments. At the level of the stifle, the line merged into the lateral region of the *Fascia genus*, making contact with the *Capsula articularis* and the *Ligamentum collaterale laterale* of the *Articulatio femorotibialis*. Further along, it is integrated into the broad fascia sheet formed by Fascia lata, M. fascia lata, and *M. gluteus superficialis*. At this point, the line split into two parts: a superficial and a profound. The superficial part extended into the *M. fascia lata* and *Pars glutea of the M. cutaneus trunci* and passed within the *Fascia superficialis* along the lateral side of the trunk, over the *Scapula* and the *M. biceps brachii*. In this region, the superficial fascia and the superficial layer of the deep (profound) fascia are closely associated with the broad *M. brachiocephalicus* (*M. sternocleidomastoideus*) and continue in a cranial direction to the muscle insertions in the cervical part of the dorsal midline, at the mastoid process of the temporal bone and at the *Fascia parotideus*. Rostrally, it connected to the *M.*

masseter (SDL), to the dorsal midline of the suboccipital region, making fascial contact with the *Os occipitalis* and the *M. temporalis* (SDL).

In the deep part of the lateral line, the myofascia from the *M. gluteus superficialis* extended over the *Tuber coxae*, *Os ilium*, entering into the *M. obliquus abdominis internus* and its aponeuroses via myofascial expansions into the *M. obliquus externus abdominis* and its aponeurosis. Myofascial expansions connected it to the *M. obliquus externus abdominis*, which continued over the *Arcus costalis* and into the *Mm. intercostalis externus et internus*, displaying the zig-zag pattern (as shown in **Figure 1**). The connection from the external intercostal muscles onto the *M. splenius* was present via the *Fascia spinocostotransversalis* under the *M. serratus dorsalis cranialis*. The splenius muscle was attached in the midplane to the *Lig. nuchae/Funiculi nuchales and* originating cranially from *Processus mastoideus* (Os temporalis) and the *Crista nuchalis* (*Os occipitalis*).

A cranial connection between the superficial and the profound parts of the LL was dissected in the Temporomandibular joint (TMJ) region. Additionally, another connection was identified between the splenius muscle and the broad fan of the brachiocephalicus muscle epaxially in the mid cervical region.

A caudal entrance to the profound part of the LL was identified *via* the tail, involving the caudal intertransverse muscles, *Mm. intertransversarii dorsalis and ventralis caudae*. These muscles were isolated at the lateral border of the proximal coccygeal vertebrae dorsal and ventral to the *M. coccygeus*. Both parts are connected to the *M. gluteus superficialis*, the dorsal part attaching to the sacropelvic fascia and local epimysium, and the ventral part integrating into the medial part of the muscle. Proximal to the *Vertebrae coccygeae* 5 - 7, the intertransverse muscles appeared as visible muscle bellows, transitioning distally into very thin muscle layers that continued into the distal parts of the tail.

Function: The structures in the common hindlimb part of the LL abduct the hindlimb. The superficial part laterally (flexes) and ventrally flexes the head, neck, and trunk, whereas the profound part laterally flexes and dorsally extends the same regions. The broad cervical fusion of the two parts of the LL serves to stabilize the neck latero-laterally. The tail part of the deep line laterally flexes the tail.

Deep Dorsal Line, DDL

The deep dorsal line originated dorsally at the tip of the tail and continued in a proximal direction into the tendinous bands from *M. sacrococcygeus dorsalis pars lateralis* and *medialis* (*M. sacrocaudalis lateralis et medialis*) (**Figure 2(b)**). The line followed these muscles in a cranial direction along the coccygeal vertebrae, over the sacrum, and continued and merged into the transversospinal muscle group, the *Mm. transversospinalis,* of which the *Mm. multifidi* were the most prominent in the lower lumbar region. The medial part of the *M. sacrococcygeus dorsalis* merged into the *M. multifidi* at the level of the lumbosacral transition, whereas the lateral part merged at the upper lumbar vertebrae. The DDL attached and connected via myofascial expansions to the SDL (*M. biceps femoris and M. semitendinosus*) at the *Tuber ischiadicus* region. The DDL continued with the transversospinal system along the *Columna vertebralis*, the lumbar, thoracic, and

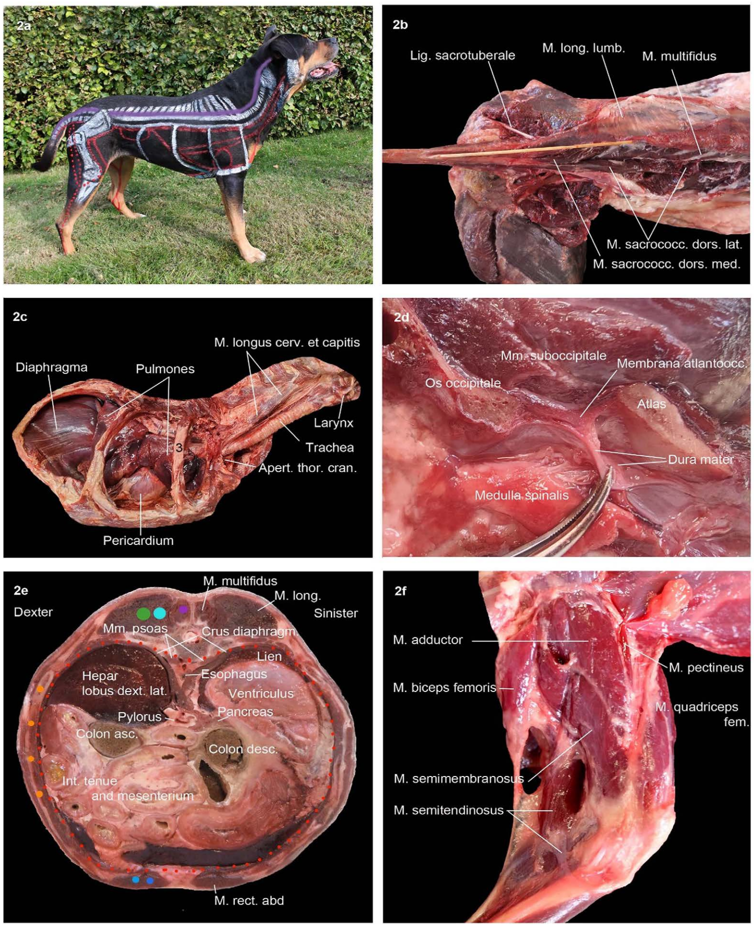

Figure 2. In Figure 2(a), the two deep myofascial kinetic lines, the Deep Dorsal (DDL, purple) and the Deep Ventral Line (DVL, red), are painted in their full extension on a dog. Figures 2(b)-(e) illustrate overviews and detailed dissections of the DDL and DVL lines, and Figure 2(e) includes a transverse overview of the location of the lines passing the trunk. In Figure 2(b), the dorsum of the lumbosacral and coccygeal part of the dog is dissected. The *M. sacrococc. dorsalis pars lateralis and medialis* is exposed. The medial part fuses into the *M. multifidus* at the lumbosacral transition, the lateral part continuing onto the mid-lumbar region. Also, the *Lig. sacrotuberale*, a part of the SDL and SL is exposed. Figure 2(c) is an overview of the cranial part of the canine trunk. Cranial is to the right. From the dorsal part of the DVL, the *M. longus cervicis and captis* are shown, from the mid part of the line, the *Diaphragm*, the fasciae in relation to the thoracic organs and the progress through the *Apertura thoracis cranialis* into the cervical structures (*Trachea*, *A. carotis communis* and *Truncus vagosympaticus*) situated in the *Fascia pretrachealis* and onto the *Larynx* and the pharyngeal region. Figure 2(d) illustrates the canine myodural bridge, a part of the DDL located in the atlanto-occipital transition. The bridge is a connection between the *Mm. suboccipitales*, the *Membrana atlantooccipitalis* and the *Dura mater*. Figure 2(e) is a transverse section at the level of the 12th thoracic vertebrae. The locations of the lines are illustrated with coloured spots. The SDL (green), the SVL (light blue), the LL (orange), the FL (dark blue), the SL (aquamarine) and the DVL (red). Notice the close connection between the Crus of the Diaphragm and the Mm. *psoas* dorsally. In Figure 2(f), the medial side of the thigh is dissected. *M. gracilis* has been removed. The *M. adductor* and the *M. pectineus* are visible and present the inlets to DVL in the pelvic cavity. Additionally, the distal tendinous part of *M. semitendinosus* presents the medial part of the hindlimb sling of the SDL.

cervical region. At the cervical region, *M. semispinalis* branched into *M. biventer cervicis* and the *M. complexus*, both inserting on the *Os occipitalis*. The fibrous *Lig. supraspinosus* was found to be a part of this line, and cranially at the cervico-thoracic junction, the ligament transitioned into the elastic *Lig. nuchae*, which progressed from the first thoracic to the second cervical vertebrae (*Axis*). Between *Os occipitalis* and *Atlas*, a myodural connection (myodural bridge, **Figure 2(d)**) between the suboccipital muscles (*M. rectus capitis dorsalis minor et major*), the *Membrana atlantooccipitalis* and the *Dura mater* was observed.

Function: The structures of the deep dorsal line act in extending and stabilizing the columna vertebralis in its full length.

Deep Ventral Line, DVL

The three-dimensional deep ventral line was a complex and branched system that encompasses both somatic and visceral components. It was dissected in one piece.

The origin of the line was identified in the hindlimb with several entrances into the pelvic cavity (**Figure 2(f)**).

In the hind paw, the DVL began at the insertion of the *Tendo m. flexor digitorum profundus* at the distal phalanx II-V. It proceeded proximally on the plantar side of the *Ossa metatarsi*, where the four branches of the tendons (II-V) fused at the midpart of the metatarsus. A retinaculum of connective tissue was arranged over this fusion. Proximally, at the level of the distal row of the tarsal bones, the deep flexor tendon branched into two: the tendon from 1) the *M. flexor digitorum medialis* and 2) *lateralis*. Continuing proximally, the DVL followed the profound flexor muscles, which connected to the deep caudal layers of the *Fascia genus*. The fascia became denser on the medial side of the stifle, where it merged into the *Lig. femorotibialis collateralis medialis*. From here, it proceeded towards the pelvic inlet along the *M. adductor major et minor* and the broad tendon of the *M. pectineus*, which progressed proximally in close contact with *Facies aspera* on the femur.

The ventral part of the tail, including *M. sacrococcygeus ventralis*, *pars lateralis et medialis*, was found to be a part of the line and entered from the caudal into the pelvic cavity. The ventral tail muscles continued at the ventral surface of the sacrum cranially into the *Lig. longitudinalis ventralis*.

From the pelvic cavity, the DVL extends cranially and is described as three distinct parts: 1) dorsal, 2) intermediate, and 3) ventral. This is to be able to explain the cranial progress in the best way (**Figure 2(a)**).

The **dorsal part** continues from the ventral tail muscles into the *Lig. longitudinalis ventralis* until the *M. longus colli* at the upper thoracic vertebrae. The line passed through the *Apertura thoracis cranialis*, into the *M. longus cervicis et capitis* (**Figure 2(c)**), and to the *Mm. rectus capitis ventralis* at the base of the cranium at the *Os occipitalis*, *pars basilaris*.

The **intermediate part** of the line included the myofascial expansions between the *M. pectineus* and the *M. psoas minor* at the *Os pubis* and from the adductor major and minor to the *M. psoas major* and *M. iliacus*. The intermediate part was found to be directed cranially along the psoas muscles, where it continued into the *Crus diaphragmatica dexter et sinister* (**Figure 2(e)**). Along the abdominal cavity, the line expanded into the mesenterial structures of the gastrointestinal (Figure 2(e)) and the urogenital tract as a subserosal lining to the *Peritoneum*. This arrangement formed a branched 3-D network of connective tissue in and around the parenchymal tissue of the inner organs, including also ligaments and connections between the inner organs and the somatic locomotive system (Table 2). The intermediate part extended cranially as the subserosal lining of the structures merging through and over the Diaphragm, such as the *Esophagus*, *N. vagus*, *V. cava*, *Aorta*, *Ductus thoracicus*, *V. azygos dexter* and with the dorsal continuation of *Mm. psoas major et minor* (Figure 2(e)). Within the thorax, the intermediate part served as a subserosal lining to the *Pleura*, encompassing the Mediastinum, the Pericardium, and the *Lig. phrenicopericardii*, the mediastinocardial ligament, the pulmonary (*Pleura pulmonalis*) and the cardial lining (*Epicardium*), as well as the ligaments and contacts between the organs and the basic skeleton of the thoracic organs (Figure 2(e)).

The subpleural lining at the *Apertura thoracis cranialis* merged with the *Mm. Scalenus dorsalis* and *medius* thereby adding an "external" connection to the line and connection to the first costae, the lower cervicals, and the *Fascia prevertebralis* and *Fascia pretrachealis*. These fasciae enclosed the hypaxial anatomical structures (*A. carotis communis*, *V. jug int. et ext.*, *Truncus trachealis*, *N. vagosympaticus*, *Esophagus and Trachea*) in the cervical region. The line passed on *via* these connections towards the base of the cranium, into the pharyngeal and laryngeal myofascia and the *Mm. pterygoideus lateralis et medialis*. At the cranial aperture, the DVL meets several other lines in the structures listed in Table 3.

The **ventral part** of the line joined as the subserosal lining of the parietal part of the *Peritoneum* and the *Pleura*. Within the *Cavum abdominis* it formed a close connection to the epimysium of the *M. transversus abdominis,* and within the *Cavum thoracis,* the *Fascia endothoracica* being engaged in the pericardium and the *Lig. phrenicopericardia*. From the *Apertura thoracis cranialis* and towards the cranium the ventral part merged into the *M. sternohyoideus and sternothyroideus*, connecting to the laryngeal and hyoid structures of the pharynx as well as the ventral lining and the extrinsic muscles of the tongue (*M. mylohyoideus*, *M. genioglossus*, *hyoglossus*, *styloglossus and geniohyoideus*).

Function: Regarding the locomotion system, the structures of the DVL adduct and flex the hindlimb and toes. They flex and stabilize the spine via the hypaxial muscles. The DVL integrates and structurally connects the viscera with the somatic body structures related to the line.

Spiral Line, SL

The SL is one of the two helical lines that cross over the midline, contributing to axial body rotation.

The spiral line was found to be subdivided into two major parts: the spiral part and the straight part(-s). In the full line, three latero-lateral crossovers were identified. The spiral part presented two crossovers, while the straight part just one. In addition to the contralateral straight part, an ipsilateral straight part was isolated.

Table 2. Overview of some of the major fascia connections between the subserosal insertional fascia and the somatic/locomotor system in the dog.

Organ	**Connecting structures**	**Connections to the somatic/locomot. system**
Liver	*Lig. triangulare dexter*	*Diaphragma, Centrum tendineum* *M. transversus abdominis and aponeurosis*
	Lig. triang. sinister	*Diaphragma pars costalis*
	Lig. coronarius	*Centrum tendineum diaphragmatis*
	Lobus caudatus, proc. caud	*M. psoas major et minor* (*the ventral part of Diaphragma*)
	Lig. teres hepatis/falciformis	*M. rectus abdominis*
Ventricle	*Esophagus/Cardia,*	*The ventral part of the Crus dexter diaphragmatis*
	Omentum majus, *Lig. gastrophrenicum*	*Centrum tendineum, Crus sinister diaphragmatis*
Intestinal tract Intestinum tenue	*Mesoduodenum, jejunum, ileum*	*M. psoas minor/major,* *Crus dexter/sinister diaphragmatic*
Rectum	*Adventitia*	*M. sphincter ani externus* *M. levator ani* *M. sacrococc. ventralis* *Indirectly to M. biceps femoris via connection to* *Lig. sacrotuberale*
Lien	*Omentum majus,* *Lig. phrenicolienale*	*Centrum tendineum,* *Crus sinister diaphragmatis*
Gl. adrenales	*Adventitia*	*Mm. psoas major and minor, prox part*
Kidney	*Subserosal fascia, dorsal part of the capsula adiposa, trabecular attachments from the capsula fibrosa renalis*	*Mm. psoas major et minor* *M. transversus abdominis* *Diaphragma pars lumbalis* *Crus dexter diaphragmatis* (*right kidney*)
Ureteres	*Adventitia*	*Ventrally along the Mm. psoas major and minor*
Ovarium	Subserosal fascia of *Processus vaginalis*	*Mm. obliquus internus, externus and transversus abdominis via Anulus inguinalis internus et externus and closure to the Canalis femoralis.*
	Mesovarium *Lig. ovarii proprii*	Via the *Lig. latum uteri* and to the *M. transversus abdominis* and ventral surface of *Mm. psoas major and minor*
	Lig. suspensorium ovarii	Over the right and left kidney and cranially to the *M. transversus abdominis* and dorsal on *pars costalis of the M. diaphragmatic*
Testis	Subserosal fascia of *Processus vaginalis and mesorchium*	*Mm. obliquus internus, externus and transversus abdominis via Anulus inguinalis*
	Proximal connections from the site of origin, *mesonephros*	Connections alongside the *A. testicularis to Mm. psoas major and minor* to the offspring from the *Aorta*, cranial to the kidney
Vesica urinaria	*Lig. vesicae lateralis*	*M. transversus abdominis*
	Lig. vesicae mediana	*Fascia rectus, M. rectus abdominis*

Continued

Uterus	*Lig. latum uteri*	Mid part of *M. transversus abdominis*
	Lig. teres uteri	*Mm. obliquus internus, externus and transversus abdominis and Anulus inguinalis*
Ductus deferens	*Plica ductus deferentis*	*Mm. obliquus internus, externus and transversus abdominis*

Table 3. Lines related to, as well as involved in the *Apertura thoracis cranialis*.

Lines	**Structures**
SDL	*M. longissimus. thor. et cerv.* *M. spinalis*
DDL	*Mm. spinotransv., Lig. nuch.*
DVL	*M. longus colli, Fascia cervicalis, M. scalenus*
SVL	*M. sternomand., M. rectus thoracis*
LL	*M. splenius, M. brachiocephalicus, M. omotransv.*
SP	*M. rhomb. cerv., M. serratus ventralis pars cerv., M. longissimus dorsi, M. spinalis*
FLPL	*M. brachiocephalicus, M. omotransversarius*
FLRL	*M. trapezius et rhomboideus. pars cerv.*
FADL	*M. pectoralis transv. et desc.*
FABL	*M. trapezius cerv. et thor.* *M. pect. asc.*

The spiral part of the SL began in the *M. splenius*, extending caudally into the *M. rhomboideus cervicis,* reaching approximately the level of the C6,7 and TH1,2. Here, the line crosses the midline *via* the medial epimysium of the rhomboid muscle, which, over the dorsal midline, was merged with the epimysium of the contralateral rhomboid muscle. Concurrently, the line also connected to the crossing over of the dense aponeurosis of the *M. serratus dorsalis*. Continuing ventrally, the line proceeded into the caudal part of the *M. serratus ventralis* and further on to the *M. obliquus externus abdominus* (*M. obl. ext. abd.*). The second crossover occurred ventrally as it followed the *M. obl. abd. ext.* into the aponeurosis, reaching the ventral midline and the *Linea alba*, then crossing into the aponeurosis of the *M. obliquus abdominus internus*, guiding the line back to the side of origin (**Figure 3(b)**). Moving along the internal oblique abdominal muscle, the line progressed to the *tuber coxae* where the tension lines continued into the *M. tensor fascia lata* and the *Fascia lata* itself. The *Fascia lata* directed the line toward the extensor compartment of the *Regio cruris,* contacting the *M. tibialis cranialis*. The line then formed a sling following the tendon medially to the proximal part of the *Os metatarsus II*, continued in a medial to lateral direction over the plantar side of the metatarsal region in a thin double-layered retinacula like band situated at the plantar and dorsal side of the superficial digital flexor tendons. Laterally, it connected to the tendinous *M. abductor digiti V*, leading the line to the lateral side of the *Tuber calcanei*. Here, it merged into the attachment of the biceps tendon, a component of the common calcanean tendon, and into the straight part of the line.

The straight part of the line continued from the Tuber calcaneus proximally via the biceps portion of the *Tendo calcaneus communis* and into the *M. biceps femoris*. The line proceeded into the profound parts of *M. biceps femoris* and into the *Lig. sacrotuberale*, which branched proximally in the sacral region. A connection was discovered to not only the apex of the sacrum but also to the dense fascia lining on the medial side of the ilium and the dorsum of the sacrum, where it enveloped the *Mm. sacrococcygei dors/Mm. mulitifidi*. This fascial lining was found to be a caudal extension of the dorsal layers of the *Fascia thoracolumbalis*, TLF, which also included the epimysium of the *M. long. lumborum* and *M. iliocostalis*. From the iliac wing, the line is split into two branches (**Figure 3(g)**). One branch crossed over to the contralateral side within the continuation of the thoracolumbar fascia (TLF) (**Figure 3(d)**) and, from here, continued into the SDL, terminating in the cranial direction at the contralateral side of the origin. The other branch ascended cranially on the ipsilateral side as the SDL, concluding at the side of the origin.

Function: The function of the structures of the two major SL parts (the spiral and the straight) indicates that the spiral part is involved in rotation and flexion of the trunk correlated with lateral flexion of the neck, and the straight parts stabilize and extend the dorsum of the trunk uni- and/or bilaterally. The spiral and the straight part support each other by acting antagonistically, ensuring stability and alignment during rotational movements. The line is dominant in canter.

Functional Line, FL

The FL was found to consist of two distinct parts, a dorsal and a ventral, each featuring a midline crossing. One over the dorsal midline and one over the ventral. Notably, the line started and ended on the same side of the body. An additional ipsilateral branch was identified in the dogs.

The dorsal part of the FL, started in the axillary region in the aponeurosis of the *M. latissimus dorsi*. The latissimus myofascia extended obliquely from the axillary region in a dorsocaudal direction into the dorsal superficial layers of the *Fascia thoracolumbalis* (TLF). Crossing over the midline of the TLF at the dorsum, it transitioned to the contralateral side (**Figure 3(b)**). At the level of the ileal wing, the line merged into the fascia of the *M. gluteus superficialis* and the *M. tensor fascia lata*, embedded into the dense fascia sheet overlying the *vastus lateralis of the M. quadriceps femoris*. The dense fascia sheet is comparable to the human iliotibial tract. Distally, it progressed to the lateral part of the *Fascia curis* just distal to the stifle joint, next- and lateral to the *Margo cranialis* (*Crista*) *tibia*. From here, the line turned into its ventral part.

The ventral part of the line commenced distal to the stifle joint, medially at the tibia within the aponeurosis from *M. gracilis* beneath the insertion of the *M. sartorius pars cranialis*. Continuing proximally and medially on the thigh, it proceeded into the *Tendo symphysialis* ventral to the pubis. Here, the line crossed over to the opposite site (the side of origin, **Figure 3(b)**) and continued into the *Vagina fibrosa of M. rectus abdominis* as well as the muscle itself. It expanded cranially into the *M. pectoralis ascendens* (*s. profundus*) and towards the axillary region, where it reunited with the origin of the line in *M. latissimus dorsi*.

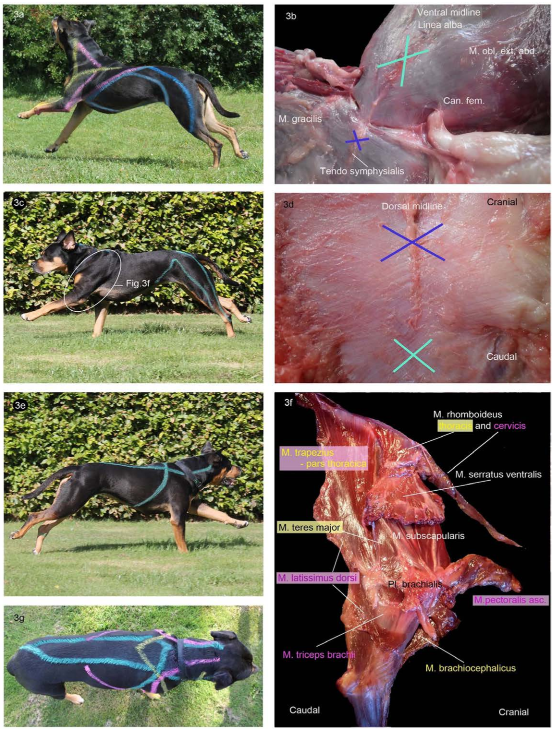

Figure 3. **Figure 3(a)**, **Figure 3(c)**, **Figure 3(e)** and **Figure 3(g)** present the flow of the helical lines, the Functional Line (**Figure 3(a)**, FL, blue), the Spiral Line (**Figure 3(c)**, **Figure 3(e)** and **Figure 3(g)**, SL, aquamarine), and the Front Limb Protraction Line (**Figure 3(a)** and **Figure 3(g)**, FLPL, yellow) and the Front Limb Retraction Line (**Figure 3(a)** and **Figure 3(g)**, FLRL, pink) painted on a dog. **Figure 3(b)** and **Figure 3(d)** illustrate the bilateral connections at the ventral and the dorsal side of the trunk. **Figure 3(f)** shows the medial aspect of the proximal front limb region (outlined in **Figure 3(c)**). Notice in **Figure 3(a)** and **Figure 3(g)** the connection between the superficial front limb lines and the helical lines. In **Figure 3(b)**, the abdominal and pelvic region is dissected, and the collagen fibres in the aponeurosis of the *M. obl. ext. abdominis* illustrate the oblique direction towards the ventral midline (Linea alba) and to the contralateral side. The second SL cross (aquamarine cross). In the pubic region, the *M. gracilis* crosses over at the *Tendo symphysialis* (blue cross). In **Figure 3(d)**, the lumbosacral region of the *Fascia thoracolumbalis* is dissected. The dorsal FL crosses in the lumbosacral region (blue), and the dorsal and third SL cross (aquamarine). **Figure 3(f)** shows the medial aspect of the brachial region, including several of the structures of the Front Limb Lines. The front limb was dissected and separated from the trunk by cutting the large cranial, caudal, dorsal, and ventral extrinsic muscles, the *M. serratus ventralis*, the *Plexus brachialis* and the axillary blood vessels. The *M. pectoralis asc.* is reflected in the cranial direction. The FLPL (yellow text) includes the *M. trapezius pars thoracica* (also included in the FLADL) and the *M. brachiocephalicus* (also included in the superficial LL). The FLRL (pink text) includes the *M. rhomboideus cervicis* (also included in the SL), the *M. pectoralis ascendens* and the *M. triceps brachii*. The Deep Front Limbs lines FADL (yellow box) and FABL (rosa box) comprise FADL, the *M. rhomboideus thoracis*, the *M. teres major,* and the medial fascia sheet distal to the Scapular hilus region (with the *Plexus brachialis*, *A. and V. axillaris* etc.); FABL, *M. trapezius pars thoracica*, *M. pectoralis ascendens* and the *M. latissimus dorsi*.

The ipsilateral branch of the FL (**Figure 3(b)**) extended from a caudal portion of the ipsilateral *M. latissimus dorsi* and branched off at the last costae. The ipsilateral branch connected to the caudal part of the *M. obliquus abdominis externus*, extending towards the tuber coxae of the Ala ossis ilii, where both parts of the *M. sartorius* originated. The line continued *via* the sartorius muscle to its' distal attachment in the medial fascia genus, where the *M. gracilis* was also inserted.

Function: The three parts of the FL support each other in cross-diagonal gaits and movements, especially trot (dominant gait). The myofascial structures in the dorsal part retract the front limb and facilitate an abduction and propulsion of the contralateral hindlimb, while extending and axially rotating the back and lumbar regions. The myofascial structures of the ventral part stabilize and counteract excessive extension and rotation of the trunk, acting as an antagonist to the dorsal part. The structures in the ipsilateral branch stabilize the lateral side of the thoracolumbar region on the ipsilateral side, preventing a lateral flexion, maintaining body alignment as well as stabilizing the medial part of the proximal hindlimb when the dorsal part of the line contracts.

The Superficial Front Limb Lines

Four front limb lines were identified and isolated. Two superficial: the front limb protraction line and the front limb retraction line, both spanning proximally to distally in the front limb. Additionally, two deep front limb lines were dissected. The Front limb Adduction Line (FADL, adduction and external rotation) and the Front Limb Abduction Line (FABL, abduction and internal rotation). These lines were regional slings in the brachial and proximal antebrachial region.

The lines are presented as four separate lines, collectively contributing to the comprehensive 3-D front limb movement and the function described as the active moment in the gait cycle (**Table 4**).

Front Limb Protraction Line, FLPL

The FLPL was dissected, and two proximal entrances belonging to the extrinsic extremity muscles was identified. Cranially, the *M. omotransversarius* and *M. brachiochephalicus*. The latter muscle had a broad origin along the dorsal midline of the neck and extended with myofascial expansions over the *Art. humeri and cubiti* towards the digital extensor muscles. At the cubital level, the superficial and the deep fascia layers fused, increasing the contact between the fascia layers. The second entrance was caudo-dorsal in the *M. trapezius pars thoracica* and *M. rhomboideus thoracis,* attaching to the dorsal third of the *Scapula* on respectively, the lateral and medial sides. The protraction line continued cranially over *M. supraspinous*, the cranial part of *M. subscapularis,* and over the *Art. humeri*. Here, it is attached to the M. biceps brachii and, further on, to the extensor group, where the cranial and caudal parts merge into the brachiocephalic aponeurosis. From here, the line extended distally along the extensor group to the *Phalanx distalis*.

Function: The function of the structures of the FLPL is to protract the front limb. They rotate the proximal part of the scapula around the centre of motion (COM) in a caudal direction and the distal part in a cranial direction. The humeral joint, the elbow, the carpus, and the paw extend. These functions predominate in the protraction phase and collaborate with the structures of the other front limb lines throughout the subsequent movement phases of the gait cycle. The structures in the protraction line act antagonistic to those in the front limb retraction line. The front limb protraction line connects to the superficial LL via *M. brachiocephalicus*.

Table 4. Structures shared by the FADL, the FABL and other canine kinetic myofascial lines, respectively.

Line	Structure	Connecting line
FADL	*M. supraspinatus* *M. rhomboideus thor.*	FLPL SL, FLPL
FABL	*M. trapezius* *pars cervicis* *pars thoracis* *M. pect. ascendens* *M. latissimus dorsi*	 FLRL FLPL SVL, FL FLRL, FL, Ipsilateral part of FL

Front Limb Retraction Line, FLRL

The FLRL also had two proximal origins belonging to the extrinsic extremity muscle groups. The craniodorsal start of the line included the *M. trapezius pars cervicalis*, situated in the superficial layers of the *Fascia cervicalis*, and the *M. rhomboideus cervicis*. Both muscles attached to the intrinsic muscles on the *Scapula*, laterally to the *M. infraspinosus* and medially to the caudal part of the *M. subscapularis*. Both sides continued into the *M. triceps brachii* and *M. tensor fascia antebrachia* and onto the digital flexor compartment. The second entrance caudodorsally along *M. latissimus dorsi* extended into its' aponeurosis into the axillary region. The fascial expansions from the latissimus muscle continued distally to the medial side of the digital flexor compartment and the fascial sheet of the digital flexor muscles. Here, the two branches merged and continued distally along the phalangeal flexor myofascia to the distal phalanx of the toe.

Function: The function of the structures in the front limb retraction line is to retract the front limb, rotating around the centre of motion at the level of the proximal third of the scapula. The proximal part of the scapula rotates in a cranial direction, and the distal part in a caudal direction. The humeral joint flexes, the elbow extends, and the carpus and the paw flex. The line is the dominant line during the initial phase of the retraction and collaborates with the other front limb lines throughout the subsequent phases of a gait cycle. The retraction line acts antagonistically to the front limb protraction line. The front limb retraction line connects directly to the FL and the ipsilateral part of the FL via the M. latissimus dorsi and the SVL via the M. pectoralis ascendens.

Front Limb Adduction Line, FADL

The FADL, arranged as a proximal sling, originated dorsally in the *M. rhomboideus thoracis*, where it connected to the medial side of the *Scapula* and the

Cartilago scapula. Along the lateral side of *Scapula*, it extended as a flat fascia layer along the *Margo dorsalis scapula*, over the *Spina scapula* towards and into the *M. supraspinatus*. Moving distally, the line traverses over the *Art. humeri* to the medial aspect of the joint where the *M. supraspinatus* and the dorsal part of the *M. pectoralis transversus* merged into a medial subscapular fascia sheet. This fascia sheet was located ventrally to the "hilus region", where the *Plexus brachialis* and *A. V. axillaris* entered the front limb. The fascia sheet continued into the distal part of *M. teres major* and followed this muscle in a dorsal direction to the *Angulus caudalis scapula* and into the *M. rhomboideus thoracis*, completing the "sling".

Function: The structures in the FADL act on the proximal part of the front limb, adducting and outwardly rotating the distal part during the initial phase of the protraction and landing phase. The adduction brings the limb close to the centre of body mass for balance and stability, while the external rotation extends the front limb, facilitating touch down initially contacting the surface on the caudal and lateral aspects of the paw.

Front Limb Abduction Line, FABL

The FABL, also arranged as a proximal sling, started in the *M. trapezius pars thoracica* and continued in a cranioventral direction into the *M. infraspinatus* and *M. deltoideus pars scapularis*. The sling extended into the *M. deltoideus pars acromialis*, to the *Fascia brachialis*, forming a broad band, which passed in a medial direction over the *Art. humeri*. Tension fibres were clearly observed traversing over the *M. biceps brachii* in a latero-medial direction. The fibres continued onto the ventral surface of *M. pectoralis transversus* and *ascendens* from where they extended into the cranial and axial aponeurosis of *M. latissimus dorsi*. Following the latissimus dorsi in a caudodorsal direction, this sling ended and reconnected with the *M. trapezius pars thoracica*.

Function: The structures in the FADL act on the brachial and the proximal antebrachial region, abducting and internally rotating the proximal part of the front limb. The line is particularly active during the initial stage of the retraction phase, facilitating abduction and inward rotation of the front limb to support the forward motion of the trunk during the weight-bearing retraction phase.

4. Discussion

General

To the authors' knowledge, this is the first study in which the 11 canine kinetic myofascial lines have been dissected, verified, and described. The lines were found to be very similar to the Human and Equine Kinetic Myofascial Lines, except for specific regions where there were differences in the anatomy and posture of the three species, their diverse roles as animals (predator versus prey animal), and thereby also their biomechanics. Neither is the author aware that the three new canine branches have been described before. The branches were found in relation to the Superficial Dorsal Line (SDL), the Spiral Line (SL), and the Functional Line (FL), the latter two observed in humans [1] but not in horse.

Biomechanical differences between horses and dogs reflect their natural roles as prey (horse) and predator (dog). Horses are adapted for endurance running and high-speed movement, with a well-developed recoil system throughout several anatomical levels, allowing for efficient energy recycling [17]-[20]. The predator, in this case, the dog, is basically designed for endurance but also to chase and hunt. Therefore, the anatomy reflects this with considerable muscle force for acceleration to catch up with prey, but also body stability and flexibility to be able to perform fast changes in both speed and direction during the chase.

Another characteristic feature of canine anatomy, as observed in the dissections, was the anatomy and topography of the extrinsic extremity muscles and myofascia. Compared to the horse, the canine muscles had broader origins, attachments at the trunk, and long and distally wide insertions in the antebrachial and crural regions. The biomechanical impact of this is to shorten the lever of the extremities. The length of the lever alters with the gait and the dog breed. A shortened lever optimizes the function and force from the myofascial slings in rotating the extremities around the hip- and shoulder regions (local centres of motion, COM). It lowers the COM, which supports stabilization and acceleration, manoeuvring and fast changes of speed and direction. Several of these features have basically been described [4] [6] [7] [21]. Athletic and forceful properties are favoured and bred in modern dogs to push their performance to the highest competitive level. The challenge is now how to maintain a long-term biomechanical durability in the dogs, preserving a correct functional balance and athletic capacity without overstepping the upper limit of the biomechanics in the athletic, forceful, and fast performances. Understanding the 3-D interactions and balance between the myofascial kinetic lines in normal compensatory and pathological patterns provides us with an essential tool to understand and evaluate the biomechanics of dogs.

Some of the limitations of the study were the difficulties in some places to observe the lines of tension/myofascial expansions in the small and thin dogs, although this problem was solved by changing the angle of the light sources and observing via the camera screen. Additionally, possible variations in a single breed were not possible to study as the donated dog material was limited. On the other had, this study showed the broad presentation of the lines within several dog breeds, as also observed with the horses [2] [3].

The Superficial Dorsal Line and the Flexion Sling

The canine superficial dorsal line is in many ways like the equine, but differences were found in the thoracolumbar region, the hindquarters, and the foot. In the lumbar region, the diameter of the canine iliocostalis myofascia was almost similar to the longissimus, and the insertion was located at the iliac wing. This was very different to the horse, where the iliocostalis was significantly smaller than the longissimus lumborum, terminated and fused in the deeper layers of the TLF at the level of L2-L4. Laterally, the muscle was covered by *M. serratus dorsalis* [22]. In the canine thoracolumbar transition, the longissimus and iliocostalis myofascia merged and at the caudal lumbar region, the epimysia of the two split and was transformed into a dorsal and ventral part attaching to the Ala ossis ilii, Ileal wing, respectively at 1) the Tuber coxae (the iliocostalis), and 2) the Tuber sacrale and the dorsal layer of the Fascia caudalis (the longissimus lumborum). This myofascial arrangement can provide the dog with a higher degree of flexibility as well as the ability to balance the lumbar, the lumbosacral, and the pelvic regions. The muscle collaboration has previously been found to establish a higher force production and facilitate spinal extension in galloping dogs [23]. In the hindlimb, the dog foot anatomy and myofascia were very different from that of the horse, digitigrade *versus* unguligrade. The canine [24] and human [1] interosseus muscles were found to be composed of multiple muscle bellows and not to be a part of the SDL. Only the superficial flexor tendon brought the line over the tarsus to the phalanx media. However, the suspensory ligament is part of the line in horses.

In the present study, an additional canine branch was discovered—the flexion sling. Aponeurotic expansions from two extrinsic muscles, the semitendinosus and biceps femoris, established a sling, which, from medially and laterally, respectively, embraced the proximal part of the *Tibia* and fused on the dorsal side, just distal to the *Tuberositas tibia*.

We believe the flexion of the stifle serves to improve and support some of the biomechanical characteristics specific to the hindquarters of carnivores. Additionally, the flexion sling meets the SVL, LL, and FL in collaboration with the stifle balancing and stabilizing of the joint. The stabilization is due to isometric contraction in the myofascia. The collaborating lines and, specifically, the flexion sling are important in the touch-down and propulsion phases of the hindlimb [25], where instabilities in the stifle can be fatal.

The Superficial Ventral Line

In the SVL, the major issue in the human myofascial lines, according to [1] and [26] [27], was the transfer of the line from the quadriceps femoris to the rectus abdominis muscle and fascia. In humans, the myofascial line includes a bony connection over the pelvis, which is considered and accepted as an exception to the rules. In the horse, a more direct contact was dissected via the accessory ligament to the *Caput femoris*, which headed directly into the prepubic tendon and brought the line to the rectus abdominis muscle and the rectus sheet [2] [3]. In the dog, this contact was found to be even closer as the SVL continued from the *Fascia genus* to the rectus femoris muscle over the *Fascia femoralis* and into the *Lig. inguinalis* and the *Tendo prepubicus*. From here, it projected directly into the rectus abdominis myofascia. When comparing the SVL of the biped (human) to that of the quadrupeds (dog and horse) [2], the latter were found to be a more complete line.

The Lateral Line, the Cutaneus Trunci Muscle and the Tail

The canine lateral line is like the equine responsible for a lateral flexion of the spine and abduction of the pelvic limb [2]. In both the horse and dog, lateral flexion correlates with spinal flexion (superficial LL) or extension (deep LL) of the neck and trunk. The superficial LL includes the cutaneous trunci muscle in both species, although there are morphological differences. In dogs, this muscle included 1) a gluteal part reaching over the lumbosacral junction and 2) was only a few millimetres thick. In contrast, the equine cutaneous trunci muscle was much thicker, up to 4 - 7 cm, focussed the contraction around the centre of gravity, and was shown to be non-fatigable [28] [29]. There is only one level of the lateral line in humans.

In the canine DLL, an extension and connection to the tail was dissected. The intertransverse muscles are connected to the line via the superficial gluteal myofascia. The tail part of the line supports the carnivore in lateral flexion and balance during walk and trot, directional changes, or movements when balance is lost [30]. These tail connections to the DLL were not found in horses or humans.

Besides the DLL, the tail is involved in two other deep lines: the DDL and the DVL. According to [24] [31] [32], the tail is a multifunctional structure serving purposes such as insect repellence, balance in complex movements and jumps, facilitating balance when walking on narrow surfaces, and communication through body language. In a cranial direction, the tail muscles are connected dorsally to the *Fascia cauda* (an extension of the TLF) and the multifidi muscle (the DDL); ventrally, they are connected to the sacrum, the ventral longitudinal ligament and the hypaxial muscles (the DVL) and laterally, to the gluteus superficialis myofascia (the DLL). Due to the close connection between the tail and the three deep carnivore kinetic lines, the tail becomes pivotal in body balance

The Deep Dorsal Line

In contrast to humans, we have identified and dissected a DDL in both the dog and horse. It was evident that this line exists in these species, while in humans, a corresponding deep back line has not been defined due to a lack of connection to the hindlimbs [1]. In the dog and horse, a hindlimb portion was not isolated either, yet clear connections to the SDL at the *Tuber ischiadicus* were observed. Differences between bipeds and quadrupeds could partly result from evolutionary changes where a reduction in the number of coccygeal vertebrae has occurred in humans, resulting in very tiny coccygeal structures. In the horse and dog, the dorsal coccygeal myofascia were very much alike, but in the dog, they headed more cranially (mid/lower lumbar vertebrae) compared to the horse (sacrum/last lumbar vertebrae) before merging into the multifidus myofascia. This difference reflects the significance of the tail as a major balance organ and favours the carnivora compared to the horse. The biomechanical impact of the tail provides the dog with highly developed skills in terms of fast changes in speed and direction. In the cranial part of the DDL, the atlantooccipital myodural bridge resides. The indirect connection between the dorsal suboccipital myofascia and the dura mater was observed in both the horse [33] [34] and the dog [35], making the line intriguing for not only its suggested function, which includes a pumping effect of the cerebrospinal fluid, but also in pathological conditions such as myofascial restrictions, head trauma, fights, fascia diseases, etc. which might have a direct impact on the local function but also an indirect effect on the CNS.

The Deep Ventral Line

The DVL was found for both the dog, horse and human to balance the external lines, and specifically to act as an antagonist to the DDL in the dog and horse. The DVL is the most complicated of the lines due to its 3-dimensional flow and numerous branches into myofasciae and "organ skeletons" connecting to the somatic and the visceral nervous system. The somatic nervous system was found to be connected to the parts of the line dominated by the locomotion system, such as the pelvic limb, the cervical and capital region, as well as the hypaxial trunk muscles. The autonomic nervous system is connected to the parts related to the viscera and other vital structures in the abdomen, the thorax, and the cervical region. Significant differences in the line between humans and dogs/horses were observed in the groin region, which was primarily related to the sartorius myofascia. In humans and dogs, the sartorius myofascia originated from the tuber coxae and extended distomedially on to the stifle. In the horse, the sartorius had a very different course, with the origo located as a tight and fibrous connection directly to the psoas muscles. This connection might serve to enhance the stability between the equine stifle and the lumbar region. Dogs have a more flexible lumbosacral region due to a smaller, simpler pelvis with sagittal angled iliac wings, a small sacrum lacking intertransverse joints, and short cranially directed transverse processes of the lumbar vertebrae. Ventral lumbar stabilization in the dog is supported by the well-developed hypaxial iliopsoas muscles and dorsally by the epaxial longissimus and large iliocostalis muscles (SDL and SL).

The diaphragm is central to the DVL due to its specific topography, which is the transverse septum in the body, and its role in encompassing vital structures transitioning from the thoracic to abdominal cavities. An important aspect is the overlap and interaction between the diaphragmatic crura and psoas muscles, establishing a "transitional zone" of the trunk that biomechanically represents the transition of the spinal movements between the lumbar and thoracic regions, the anticlinal region. In the dog, this zone is specifically designated to one vertebra, the 10th thoracic, which possesses a high flexibility and biomechanical vulnerability. Hypaxially, this region includes structures such as the Abdominal aorta and its ventral branches (the *A. coeliaca and mesenterica cranialis*), the sympathetic *Ganglion solare* (fusion of *Ggl. coelica* and *mesentericum cranialis*), the adrenal glands, the kidneys, the liver, the pancreas, the ventricle, the *Cisterna chyli* and the vagus nerve and the epimysiae of the psoas and crura from *Diaphragma*. Tension in the subserosal fascia in this region might have a considerable impact on the basic functions of the local structures and organs.

The visceral fasciae, which are parts of the DVL, were studied by [36], who identified two major fascia types: 1) the investing fascia, located within and closely around parenchymatous cells and related to the autonomic nervous system, and 2) the insertional fascia, attaching and connecting organs to surrounding locomotive structures and related to the somatic nervous system. Their findings show that viscero-somatic interactions are present in relation to the fasciae and in this case, to the DVL.

The Spiral Line

The Spiral Line, SL, belongs to the group of helical lines involved in the cross-coordinated gaits. The dog's SL closely resembles that dissected in both horses and humans, although some significant differences were observed. One major difference observed in dogs and humans compared to horse, was the continuation of the straight part of this line into the SDL at the sacral region. In the dog and human, a flow to both ipsi- and contralateral SDLs was dissected, while in the horse, a connection only to the contralateral side was present [2] [3].

The Functional Line and the Ipsilateral Line

The FL consists of two parts: the dorsal part of the FL extends and rotates the trunk axially, and the ventral part stabilizes and protects the trunk from over-extension. Differences between the dog and horse were found, e.g., at the stifle and in the lumbar region. In the horse, the dorsal and ventral part of the line fused distal to the stifle on the *Tuberositas tibia,* whereas in the dog, the connection between the two parts was established as a bony connection between the gracilis myofascia and the epimysium of the vastus lateralis of the quadriceps femoris. In contrast to this, the human connection was dissected between the fascia lata and the gracilis muscle.

Another difference observed was the ipsilateral extension, which was dissected from the lateral thoracolumbar fascial transition to the medial thigh and the *Fascia genus*. This ipsilateral extension has been isolated in humans [1] and now in this dog study, but not in horses. Both humans and dogs exhibit high flexibility in their lumbar regions. The absence of the ipsilateral line in horses likely correlates with their considerable lumbar stability.

The Superficial and Deep Front Limb lines

In the dog and horse, the structures in the pro - and retraction front limb lines were found to be very similar, yet despite this, several significant anatomical differences were observed. One major difference was the myofascial attachment of the extrinsic muscles to the front limb. In dogs, the distal myofascial attachment was linked to the mid-antebrachial region, which differs from horses, where the extrinsic muscles attach close to or proximal to the elbow. This difference might explain the variations in posture, limb angles, and movement patterns between these two species [7]. The proximal attachments of the extrinsic front limb muscles, such as the cleidocervical part of the brachiocephalicus and the latissimus dorsi myofascia, present major differences between these quadrupeds. Unlike horses, dogs have broad attachments along the dorsal midline in the cervical and thoracolumbar regions.

The deep front limb lines, like the superficial lines, were also observed to attach more distally in dogs compared to horses. The major difference between the two quadrupeds was observed in the canine antebrachial region in terms of axial rotation, due to the mobility between the radius and ulna. The arm lines and their functions between quadrupeds and bipedal humans were obviously very difficult to compare due to the significant differences in anatomy and function.

The present anatomical knowledge of muscle function and collaboration of the locomotion system needs to be reassessed, and the widely believed roles of agonistic, antagonistic, or synergistic interactions should be reevaluated to obtain a more precise interpretation and knowledge of the effect of the myofascial connections of the locomotion system locally [37] [38] as well as in the full body perspective.

5. Conclusions

This dissection study was undertaken to evaluate the feasibility of identifying, dissecting, describing, and isolating myofascial kinetic lines in dogs and to identify the role of the tail with respect to the lines. Ordinary dissections and transverse sections of dogs were performed. The results show that eleven canine kinetic myofascial lines can be identified and described and that the tail is involved in the three deep lines (DDL, DVL, and DLL).

The canine lines were compared to human and equine lines. While the canine lines were similar in many ways to both, distinct differences were also present. These differences reflected the role of the canine as a quadruped predator with biomechanical needs for rapid speed changes (acceleration and deceleration), flexibility, and manoeuvrability, including the involvement of the tail in these lines. Additionally, two new canine branches (the ipsilateral part of the FL and the double stabilizing line in the SL) and one extension (the stifle sling of the SDL) further supported the biomechanical needs and lumbar stabilization characteristic of canines.

The topography and anatomy of the extrinsic limb muscles also supported the predator function associated with the canine lines. This study, which has dissected and isolated the Canine Myofascial Kinetic Lines, served to improve the diagnostic tools available to veterinarians, as well as significantly enhance the study and understanding of the biomechanics and compensatory mechanisms in dogs seen from a whole-body perspective.

Further studies with objective measurements of the biomechanics of the line need to be performed.

Acknowledgements

I would like to thank all who have contributed to the studies. The technicians Vibe Bøgelund Hansen and Jan Lykke for their skilled technical contributions, Mette S. Sentow and Anne S. Sentow for their contribution and help with the photography and illustrations of the painted dog. Thanks to Molly, my dog, for being willing to be painted; to Rikke M. Schultz and Tove Due for support, help, and fruitful discussions; to Rikke Wriedt, Bianca Sønderby Rothmann, and Sandra Pallesgaard Hansen for their great contributions at the start and initiation of the project, to the veterinary students and close colleges for asking critical questions, to Adrian P. Harrison for proofreading and not least to the owners of the dogs for their generous donations.

Author Contributions

VSE planned the project, dissected a major part of the study, contributed and analysed the data, made the figures and tables and wrote the manuscript.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

[1] Myers, T.W. (2021) Anatomy Trains, Myofascial meridians for Manual Therapists and Movement Professionals. Fourth Edition, Elsevier.

[2] Elbrønd, V.S. and Schultz, R.M. (2015) Myofascia—The Unexplored Tissue: Myofascial Kinetic Lines in Horses, a Model for Describing Locomotion Using Comparative Dissection Studies Derived from Human Lines. *Medical Research Archives*, No. 3, 1-22. https://doi.org/10.18103/mra.v0i3.125

[3] Elbrønd, V.S. and Schultz, R.M. (2021) Deep Myofascial Kinetic Lines in Horses, Comparative Dissection Studies Derived from Humans. *Open Journal of Veterinary Medicine*, **11**, 14-40. https://doi.org/10.4236/ojvm.2021.111002

[4] Biewener, A.A. (1989) Scaling Body Support in Mammals: Limb Posture and Muscle Mechanics. *Science*, **245**, 45-48. https://doi.org/10.1126/science.2740914

[5] Biewener, A.A. (1991) Musculoskeletal Design in Relation to Body Size. *Journal of Biomechanics*, **24**, 19-29. https://doi.org/10.1016/0021-9290(91)90374-v

[6] Biewener, A.A., Bomphrey, R.J., Daley, M.A. and Ijspeert, A.J. (2022) Stability and Manoeuvrability in Animal Movement: Lessons from Biology, Modelling and Robotics. *Proceedings of the Royal Society B: Biological Sciences*, **289**, Article ID: 20212492. https://doi.org/10.1098/rspb.2021.2492

[7] Biewener, A.A. (1983) Allometry of Quadrupedal Locomotion: The Scaling of Duty Factor, Bonecurvature and Limb Orientation to Body Size. *Journal of Experimental Biology*, **105**, 147-171. https://doi.org/10.1242/jeb.105.1.147

[8] Hyttel, P., Sinowatz, F. and Vejlsted, M. (2010) Essentials of Domestic Animal Embryology. Saunders, 69-79.

[9] Vieira, L. (2020) Embryology of the Fascial System. *Cureus*, **12**, e10134. https://doi.org/10.7759/cureus.10134

[10] Purslow, P.P. (2010) Muscle Fascia and Force Transmission. *Journal of Bodywork and Movement Therapies*, **14**, 411-417. https://doi.org/10.1016/j.jbmt.2010.01.005

[11] Purslow, P.P. (2020) The Structure and Role of Intramuscular Connective Tissue in Muscle Function. *Frontiers in Physiology*, **11**, Article 495. https://doi.org/10.3389/fphys.2020.00495

[12] Huijing, P.A. (2003) Muscular Force Transmission Necessitates a Multilevel Integrative Approach to the Analysis of Function of Skeletal Muscle. *Exercise and Sport Sciences Reviews*, **31**, 167-175. https://doi.org/10.1097/00003677-200310000-00003

[13] Huijing, P.A. and Jaspers, R.T. (2005) Adaptation of Muscle Size and Myofascial Force Transmission: A Review and Some New Experimental Results. *Scandinavian Journal of Medicine & Science in Sports*, **15**, 349-380. https://doi.org/10.1111/j.1600-0838.2005.00457.x

[14] Huijing, P.A., van de Langenberg, R.W., Meesters, J.J. and Baan, G.C. (2007) Extramuscular Myofascial Force Transmission Also Occurs between Synergistic Muscles

and Antagonistic Muscles. *Journal of Electromyography and Kinesiology*, **17**, 680-689. https://doi.org/10.1016/j.jelekin.2007.02.005

[15] Kjær, M., Langberg, H., Heinemeier, K., Bayer, M.L., Hansen, M., Holm, L., *et al.* (2009) From Mechanical Loading to Collagen Synthesis, Structural Changes and Function in Human Tendon. *Scandinavian Journal of Medicine & Science in Sports*, **19**, 500-510. https://doi.org/10.1111/j.1600-0838.2009.00986.x

[16] Magnusson, S.P., Langberg, H. and Kjaer, M. (2010) The Pathogenesis of Tendinopathy: Balancing the Response to Loading. *Nature Reviews Rheumatology*, **6**, 262-268. https://doi.org/10.1038/nrrheum.2010.43

[17] Ahmed, W., Kulikowska, M., Ahlmann, T., Berg, L.C., Harrison, A.P. and Elbrønd, V.S. (2019) A Comparative Multi-Site and Whole-Body Assessment of Fascia in the Horse and Dog: A Detailed Histological Investigation. *Journal of Anatomy*, **235**, 1065-1077. https://doi.org/10.1111/joa.13064

[18] Biewener, A.A. (1998) Muscle-Tendon Stresses and Elastic Energy Storage during Locomotion in the Horse. *Comparative Biochemistry and Physiology Part B*: *Biochemistry and Molecular Biology*, **120**, 73-87. https://doi.org/10.1016/s0305-0491(98)00024-8

[19] Wilson, A.M., McGuigan, M.P., Su, A. and van den Bogert, A.J. (2001) Horses Damp the Spring in Their Step. *Nature*, **414**, 895-899. https://doi.org/10.1038/414895a

[20] Wilson, A.M., Watson, J.C. and Lichtwark, G.A. (2003) Biomechanics: A Catapult action for Rapid Limb Protraction. *Nature*, **421**, 35-36. https://doi.org/10.1038/421035a

[21] Williams, S.B., Usherwood, J.R., Jespers, K., Channon, A.J. and Wilson, A.M. (2009) Exploring the Mechanical Basis for Acceleration: Pelvic Limb Locomotor Function during Accelerations in Racing Greyhounds (*Canis familiaris*). *Journal of Experimental Biology*, **212**, 550-565. https://doi.org/10.1242/jeb.018093

[22] Schultz, R. and Elbrønd, V. (2018) Novel Dissection Approach of Equine Back Muscles: New Advances in Anatomy and Topography—And Comparison to Present Literature. *SPG BioMed*, **1**, 1-13. https://doi.org/10.32392/biomed.28

[23] Webster, E.L., Hudson, P.E. and Channon, S.B. (2014) Comparative Functional Anatomy of the Epaxial Musculature of Dogs (*Canis familiaris*) Bred for Sprinting vs. Fighting. *Journal of Anatomy*, **225**, 317-327. https://doi.org/10.1111/joa.12208

[24] Nickel, R., Schummer, A. and Seiferle, E. (1977) Lehrbuch der Anatomie der Haustiere. Fourth Edition, Wentworth Press.

[25] Fischer, M.S. and Lilje, K.E., (2014) Dogs in Motion. Second Edition, Bonifatius GmBH.

[26] Krause, F., Wilke, J., Vogt, L. and Banzer, W. (2016) Intermuscular Force Transmission along Myofascial Chains: A Systematic Review. *Journal of Anatomy*, **228**, 910-918. https://doi.org/10.1111/joa.12464

[27] Wilke, J., Krause, F., Vogt, L. and Banzer, W. (2016) What Is Evidence-Based about Myofascial Chains: A Systematic Review. *Archives of Physical Medicine and Rehabilitation*, **97**, 454-461. https://doi.org/10.1016/j.apmr.2015.07.023

[28] Essig, C.M., Merritt, J.S., Stubbs, N.C. and Clayton, H.M. (2013) Localization of the Cutaneus Trunci Muscle Reflex in Horses. *American Journal of Veterinary Research*, **74**, 1428-1432. https://doi.org/10.2460/ajvr.74.11.1428

[29] van Iwaarden, A., Stubbs, N.C. and Clayton, H.M. (2012) Topographical Anatomy of the Equine M. Cutaneus Trunci in Relation to the Position of the Saddle and Girth. *Journal of Equine Veterinary Science*, **32**, 519-524. https://doi.org/10.1016/j.jevs.2011.12.005

[30] Wada, N., Hori, H. and Tokuriki, M. (1993) Electromyographic and Kinematic Studies of Tail Movements in Dogs during Treadmill Locomotion. *Journal of Morphology*, **217**, 105-113. https://doi.org/10.1002/jmor.1052170109

[31] Röhrmann, N., Louis, A.L. and Raabe, I. (2020) Die Hunderute—Grundlagen der osteopathischen und physiotherapeutischen Therapie. *Zeitschrift für Ganzheitliche Tiermedizin*, **34**, 147-154. https://doi.org/10.1055/a-1258-7960

[32] Kiley-Worthington, M. (1976) The Tail Movements of Ungulates, Canids and Felids with Particular Reference to Their Causation and Function as Displays. *Behaviour*, **56**, 69-114. https://doi.org/10.1163/156853976x00307

[33] Elbrønd, V.S. and Mark Schultz, R. (2019) Equine Myodural Bridges—An Anatomical and Integrative/Functional Description of Myodural Bridges along the Spine of Horses: Special Focus on the Atlanto-Occipital and Atlanto-Axial Regions. *Medical Research Archives*, **7**, 1-20.

[34] McElroy, A., Rashmir, A., Manfredi, J., Sledge, D., Carr, E., Stopa, E., *et al.* (2019) Evaluation of the Structure of Myodural Bridges in an Equine Model of Ehlers-Danlos Syndromes. *Scientific Reports*, **9**, Article No. 9978. https://doi.org/10.1038/s41598-019-46444-w

[35] Ma, Y., Tang, W., Gong, D., Li, X., Zhang, J., Sun, J., *et al.* (2021) The Morphology, Biomechanics, and Physiological Function of the Suboccipital Myodural Connections. *Scientific Reports*, **11**, Article No. 8064. https://doi.org/10.1038/s41598-021-86934-4

[36] Stecco, C., Sfriso, M.M., Porzionato, A., Rambaldo, A., Albertin, G., Macchi, V., *et al.* (2017) Microscopic Anatomy of the Visceral Fasciae. *Journal of Anatomy*, **231**, 121-128. https://doi.org/10.1111/joa.12617

[37] Huijing, P.A. and Baan, G.C. (2003) Myofascial Force Transmission: Muscle Relative Position and Length Determine Agonist and Synergist Muscle Force. *Journal of Applied Physiology*, **94**, 1092-1107. https://doi.org/10.1152/japplphysiol.00173.2002

[38] Yucesoy, C.A., Koopman, B.H.F.J.M., Baan, G.C., Grootenboer, H.J. and Huijing, P.A. (2003) Extramuscular Myofascial Force Transmission: Experiments and Finite Element Modeling. *Archives of Physiology and Biochemistry*, **111**, 377-388. https://doi.org/10.3109/13813450312331337630