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ZOOLOGY

Gross anatomy of the intrinsic muscles of the scapular and humeral joint regions in crab-eating fox (*Cerdocyon thous*, Linnaeus 1776)

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ABSTRACT. The crab-eating fox (*Cerdocyon thous*) is a wild canid with a wide distribution in South America that is susceptible to traumas due to road kills - an event in which some specimens can survive. Therefore, anatomical studies in their thoracic limbs may be a base for rehabilitation. Six dead specimens were donated by Wildlife Rescue Centre of CORPOCALDAS (Environmental Authority of the Department of Caldas in Colombia), which were then filled with silicone rubber via the common carotid artery, and later fixed with formaldehyde through the external jugular vein. One male was dissected in fresh, and after a week, the others were dissected on the scapular and humeral joint regions. The intrinsic muscles of these regions in the crab-eating fox were homologous to domestic dog, with similar characteristics in terms of shape, origin, insertion, innervation and arterial blood supply. However, the crab-eating fox did have some differences, such as its supraspinatus muscle being conformed by two bellies and attached into the articular capsule of the humeral joint in same manner as the subscapularis muscle, thus conferring greater stability to the humeral. However, the clinical and surgical approaches that must be performed in this region may be homologous to the domestic dog.

Keywords: arterial blood supply; Canidae; innervation; myology; thoracic limb.

Anatomia macroscópica dos músculos intrínsecos das regiões escapular e da articulação do úmero de cachorro-do-mato (*Cerdocyon thous*, Linnaeus 1776)

RESUMO. Cachorro-do-mato (*Cerdocyon thous*) é um canideo selvagem amplamente distribuído na América do Sul, susceptível a traumatismos por atropelamentos em rodovias, eventos nos quais alguns animais podem sobreviver. Portanto, estudos anatômicos em seus membros torácicos podem servir como base para sua reabilitação. Seis espécimes mortos foram doados pelo Centro de Resgate de Vida Selvagem da *Corporación Autónoma Regional para el Desarrollo de Caldas* - CORPOCALDAS, os quais foram preenchidos com borracha de silicone pela artéria carótida comum, e depois fixados com formaldeído através da veia jugular externa. Um macho foi dissecado a fresco e após uma semana, os outros foram dissecados nas regiões da articulação escapular e umeral. Os músculos intrínsecos dessa região no cachorro-do-mato eram homólogos às dos cães domésticos, com características semelhantes na forma, origem, inserção, inervação e suprimento de sangue arterial. No entanto, o cachorro-do-mato apresenta algumas diferenças, como músculo supraespinhal conformado por duas cabeças e unidos na cápsula articular da articulação umeral, da mesma forma que o músculo subescapular, características essas que devem conferir maior estabilidade à articulação do úmero. Apesar disso, as abordagens clínicas e cirúrgicas realizadas nesta região podem ser homólogas ao cão doméstico.

Palavras-chave: suprimento de sangue arterial; Canidae; inervação; miologia; membro torácico.

Introduction

The crab-eating fox (*Cerdocyon thous*) is a wild canid that inhabits the savannas and forests of South America (Bisbal, 1988; Berta, 1982), with sightings recorded up to 3.000 meters above sea level (Lucherini, 2015). It is of medium body size (Emmons & Feer, 1997) with a head and body length of 64.3 cm, and a tail of 28.5 cm, weighing between 5 and 8 Kg (Berta, 1982). It has nocturnal habits (Eisenberg & Redford, 1999) and an omnivorous diet based on plants, fruits, insects, snakes, lizards, frogs, fish, birds, and small mammals (Bueno & Motta-Junior, 2004). This is important because it controls the population of certain vertebrates within forests (Cabrera, Lozano, & Rueda, 1995). It is categorized by the IUCN (International Union for Conservation of Nature) as a species of least concern, since its population is relatively stable due to its great adaptability in habitat variety (Lucherini, 2015). However, the crab-eating fox is susceptible to being hit by road vehicles (De la Ossa-Nadjar & De la Ossa, 2013; Pinowski, 2005), and in some cases when they are still alive, crab-eating foxes may arrive to Wildlife Care Centers where the scapular and humeral joint regions are analyzed to determine their conditions - since at least one study in domestic carnivores has found that at least 68% of scapula fractures are etiologically caused by motor vehicle accidents (Johnston, 1993). Therefore, it is important to contribute to the anatomical knowledge of the intrinsic muscles of the scapular and humeral joint regions in order to serve as a basis and establish clinical and surgical approaches in these regions in order to rehabilitate this species.

Material and methods

From ethical source, six specimens of *Cerdocyon thous*, two males and four females that died in the Wildlife Rescue Centre of CORPOCALDAS (Environmental Authority of the Department of Caldas in Colombia) were used, which thanks to the inter-administrative agreement No. 172-2011, were donated and transported to the laboratory of veterinary morphology of the Universidad de Caldas. One male was dissected fresh, and the other specimens were filled via the common carotid artery with red-stained silicone rubber and were then injected with a fixative and conservative solution consisting of 10% formaldehyde, 5% mineral oil, and 1% phenic acid into the external jugular vein, which was also used in the fixation of the thoracic limbs of a female via intramuscular and subcutaneous applications after a necroscopic study. After one week, thoracic limbs were dissected from superficial to deep plane, emphasizing the scapular (*Regio scapularis*) and humeral joint (*Regio articulationis humeri*) regions in order to find the intrinsic muscles, and to describe their anatomical characteristics such as shape, origin, insertion, innervation and irrigation, in addition to carrying photographic records, and describing them according to the terminology of the *Nomina Anatomica Veterinaria* (International Committee on Veterinary Gross Anatomical Nomenclature [ICVGAN], 2017).

Results and discussion

The intrinsic muscles of the scapular and humeral joint regions in *Cerdocyon thous* were divided into lateral and medial groups. The first had the supraspinatus, infraspinatus, deltoideus and teres minor muscles. The second group had the subscapularis, teres major and coracobrachialis muscles (Figure 1).

The m. supraspinatus had two muscular bellies, one cranial and one caudal, where the cranial was less developed compared to the caudal, and it was separated from this by a partial intermuscular septum because there is a fusion of muscular fibers with the caudal belly on its deep part. The cranial belly arose from a fleshy form in the intermuscular septum of the caudal belly; and in the ventral two thirds of the cranial margin of the scapula together with the m. subscapularis where an intermuscular septum is formed with this. The caudal belly arose with a large fleshy area in the supraspinous fossa of the scapula and on the cranial surface of the spine of the scapula including the acromion, except the deep part of the latter. The two bellies at the level of the humeral joint formed a tendon that was inserted onto the craniolateral part of the articular capsule of the humeral joint and proximal margin of the greater tubercle of the humerus (Figure 1A and B). It was innervated by the suprascapular nerve, and its arterial blood supply was via the suprascapular artery from the superficial cervical artery by a lateral branch that supplied its cranial part, and a medial branch that passed together to the suprascapular nerve. Its arterial blood supply was via the acromial branch of the superficial cervical artery, which passed superficially on the ventral third of the cranial belly to reach the intermuscular septum between the two muscular bellies where it is deepened in order to irrigate them.

The m. infraspinatus arose from a broad fleshy form in the infraspinous fossa of the scapula and aponeurosis with origin in the scapular part of the m. deltoideus. Its origin reached the caudal surface of the scapular spine, except for the most ventral part of the latter where there is a free zone of origin. It was inserted through a tendon onto the surface to the m. infraspinatus, which was in the distal part of the greater tubercle of the humerus (Figure 1B). It was innervated by the suprascapular nerve, and its arterial blood supply was via the suprascapular artery in its cranial part, and by branches of the subscapular, caudal circumflex humeral and circumflex scapular arteries in its caudal part.

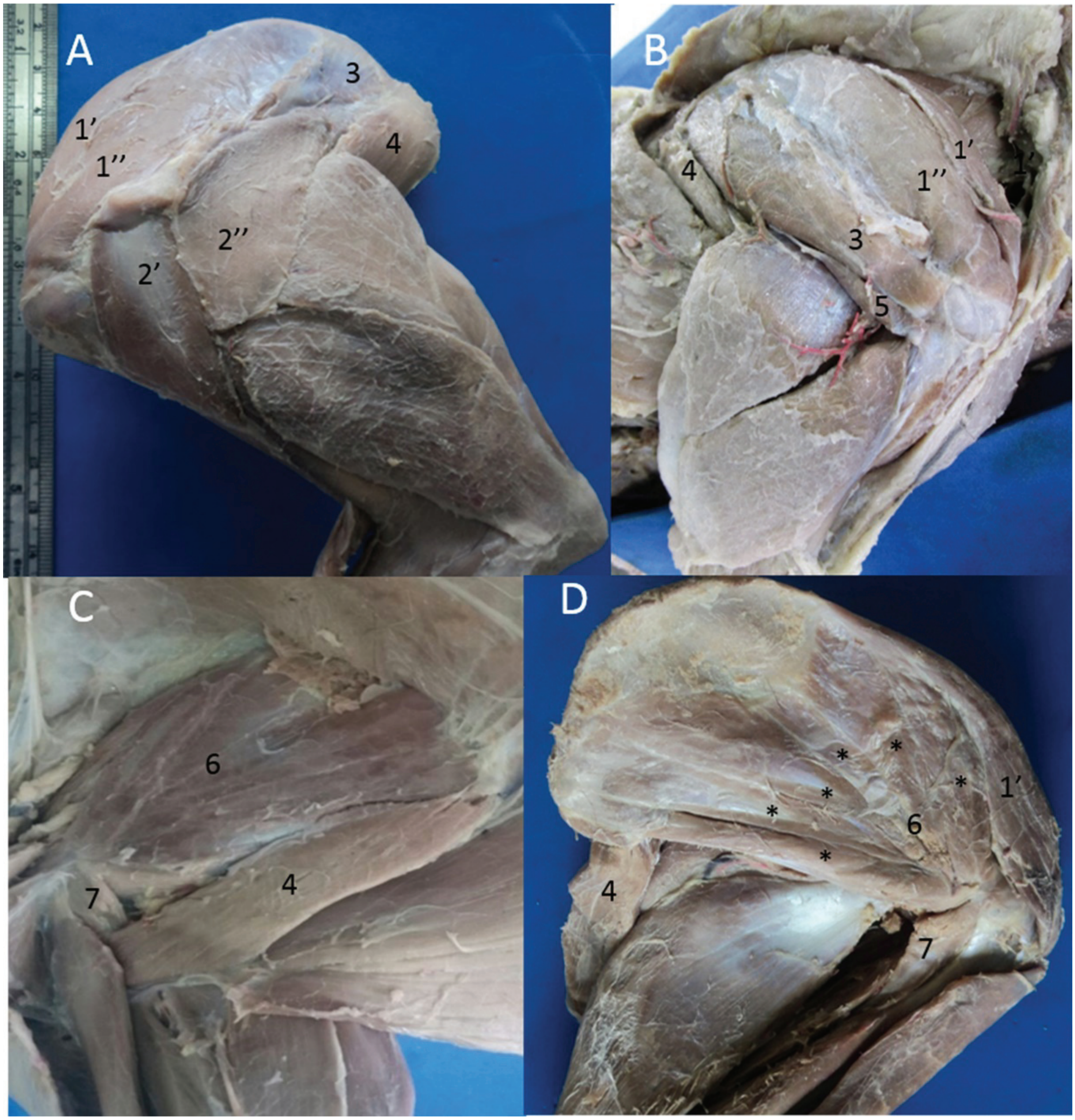

Figure 1. Intrinsic muscles of the scapular and humeral joint regions in the crab-eating fox (*Cerdocyon thous*). A) Lateral view of left scapular and brachial regions after removing the m. omotransversarius and m. trapezius. B) Lateral view after remove the m. deltoideus. C) Medial view. D) Medial view after remove the m. latissimus dorsi. 1. m. supraspinatus: 1 'cranial belly, 1' 'caudal belly; 2. m. deltoideus: 2' acromial part, 2'' scapular part; 3. m. Infraspinatus; 4. m. teres major; 5. m. teres minor; 6. m. subscapularis ⋆ (bellies); 7. m. coracobrachialis.

The m. teres minor was small and it had an aponeurotic origin through a wide tendon in the three ventral fourths of the caudal margin of the scapula until it is inserted with a tendon onto the teres minor tuberosity of the humerus (Figure 1B). It was innervated by the axillary nerve, and its arterial blood supply via by the caudal circumflex humeral artery.

The m. deltoideus had two parts - scapular (*Pars scapularis*) and acromial (*Pars acromialis*). The first arose by an aponeurosis on the ventral three quarters of the scapular spine, and the second one arose in tendino-muscular form on the ventral margin of the acromion. Both parts were fused and inserted onto the deltoid tuberosity of the humerus (Figure 1A). It was innervated by the axillary nerve, and its arterial blood supply was via the caudal circumflex humeral and subscapular arteries.

The m. subscapularis had a multipennate shape with six muscular bellies, which arose in a fleshy form throughout the subscapular fossa reaching the cranial and caudal margins of the scapula. In the cranial margin, it arose along with the supraspinatus muscle, having fibers that originate from this; and the caudal margin arose in the middle third between the origins of the teres major, minor teres and longus head of the triceps brachii muscles. It then passed distally to the m. coracobrachialis and through a tendon it is inserted onto medial surface of the articular capsule of the humeral joint and greater tubercle of the humerus (Figure 1D). It was innervated by the subscapular nerves and its caudal belly by the axillary nerve. Cranially the arterial blood supply was via the suprascapular artery and caudally via the subscapular and circumflex scapular arteries.

The m. teres major arose laterally in a fleshy form in the epimysium of m. infraspinatus adjacent to the caudal angle of the scapula inclusive the dorsal fourth of the caudal margin of the scapula and the dorsal third of the caudal belly of the subscapularis muscle (Figure 1A). Its belly was flattened latero-medially and, located ventral to the subscapular muscle, and at the level of the humerus where it passed medially to the m. coracobrachialis. It formed a wide tendon in common with the m. latissimus dorsi. It was inserted onto the tuberosity for the teres major muscle, which was placed in the space located between the crests of the major and minor tubercle of the humerus, and cranial to the origin of the medial head of the triceps brachii muscle (Figure 1C). It was innervated by the axillary nerve, and its arterial blood supply was via the subscapular and thoracodorsal arteries.

The m. coracobrachialis arose from coracoid process of the scapula through a long and thin tendon that medially surrounded the tendon of the m. subscapularis, and it passed distally to where it met the muscular belly, which formed tendinous fascicles but was inserted mainly in a fleshy form covering the medial part of the neck of the humerus, the crest of the minor tubercle, and proximal third of the humerus between the origins of the accessory and medial heads of the triceps brachii muscle (Figure 1D). It was innervated by the musculocutaneous nerve and its arterial blood supply was via the cranial circumflex humeral artery. The intrinsic muscles of the scapular and humeral joint regions in the crab-eating fox had few differences in shape, origin, insertion, and innervation to those reported in another species of the family Canidae such as the domestic dog (*Canis lupus familiaris*) (Barone, 2000; Budras, McCarthy, Fricke, & Richter, 2007; König, Maierl, & Liebich, 2005; Dyce, Sack, & Wensing, 2012; Hermanson, 2013). Important differences among the origin and insertion of these muscles have not been found among canids as the dingo (*Canis lupus dingo*) (Haughton, 1867), maned wolf (*Chrysocyon brachyurus*) (Pereira, Santos, Borges, Queiroz, & Silva, 2016) and another study in the crab-eating fox (Rodrigues, Filadelpho, Gomes, & Birck, 2013). However, it should be noted that in these species there are no reports of the formation of two bellies in the m. supraspinatus, nor the attachment of this and the m. subscapularis onto the articular capsule of the humeral joint, and the origin of the m. teres major into m. infraespinatus as occurs in our study in crab-eating fox, where we also include the innervation and arterial supply to these muscles. On the other hand, the m. infraspinatus in domestic dog can have the development of a tendon that divides into a short deep portion and a long superficial portion, where the first is inserted onto the crest of the lesser tubercle of the humerus and the second onto the greater tubercle of the humerus (Dyce et al., 2012) but the first insertion was not found in our and another study (Rodrigues et al., 2013). The m. teres minor in domestic dog and crab-eating fox had been reported as only arising into infraglenoid tubercle of the scapula (Budras et al., 2007; Rodrigues et al., 2013), which is different to our findings, where it is originated also from the caudal margin of the scapula, similar to the maned wolf (Pereira et al., 2016).

The arterial blood supply of these muscles in crab-eating fox was similar to the domestic dog, however in this last species it had been reported that the m. teres major is also supplied by the suprascapular artery; the m. teres menor by the humeral cranial circumflex artery; and m. coracobrachialis by the caudal humeral circumflex artery (Bezuidenhout, 2013; Ghoshal, 1982).

In other carnivores of digitigrade locomotion like species of the family Felidae as in puma (*Puma concolor*) (Concha, Adaro, Borroni, & Altamirano, 2004), cheetah (*Acinonyx jubatus*) (Hudson et al., 2011), lion (*Panthera leo*) (Vargas, Quintana, Barraza, & Olivares, 2017), and domestic cat (*Felis catus*), there are no reports of the differences found in the *C. thous* with the domestic dog but in the latter two there is an articular muscle of the humerus (*m. articularis humeris*) on the caudal surface of the humeral joint (Barone, 2000; Clair, 1982; Vargas et al., 2017), which is a muscle not found in *C. thous*. In the ocelot (*Leopardus pardalis*), differences are found with *C. thous* such as the division of m. supraspinatus in superficial and deep layer. In addition, the m. teres minor also originates in the tendon of the long head of the m. triceps brachii, and on the other hand, the m. teres major fuses proximally to the subscapular and infraspinatus muscles. Additionally, the m. subscapularis is fused to the articular capsule of the humeral joint (Julik et al., 2012), where the latter in *C. thous* was found as an attachment and not as a fusion. In the Euresian lynx (*Lynx lynx*) the m. supraspinatus and the m. teres minor were inserted onto the articular capsule of the humeral joint (Viranta, Lommi, Holmala, & Laakkonen, 2016), being similar to *C. thous* but different to the insertion of the m. teres minor. In the family Hyaenidae, the hyena (*Hyaena hyaena*) is different to *C. thous* due to the presence of the m. subscapularis with three heads forming three tendons that were inserted separately into the lesser tubercle of the humerus (Spoor & Badoux, 1986). In another member of the family Hyaenidae, in the ground wolf (*Proteles cristatus*), the m. deltoids has been found indivisible, and m. teres minor is inseparable from the m. infraspinatus being different to *C. thous*. But in other as the spotted hyena (*Hyaena crocuta*) (Watson & Young, 1879) and a member of the family Viverridae such as the Malabar large-spotted civet (*Viverra civettina*) (Watson, 1882) these muscles are separated similar to *C. thous*.

In carnivores with palmigrade locomotion such as a member of the family Mustelidae the ferret minor (*Galictis cuja*), there are differences such as the m. supraspinatus being formed by three bellies with an origin similar to *C. thous* but sometimes sharing fibers with the m. subscapularis. There are fibers that are fixed proximally onto the humeral joint and can be a variant inserted into lesser tubercle of the humerus. In addition, the m. teres minor may be absent (Ercoli, Alvarez, Stefanini, Busker, & Morales, 2015) differing to *C. thous* and other mustelid such as the American badger (*Taxidea taxus*) where it was always present, but in the last species the m. supraspinatus is simple and the m. coracobrachialis is not reported (Moore, Budny, Russell, & Butcher, 2013).

In members of the family Procyonidae there are differences with respect to the *C. thous*, such as in the coati (*Nasua nasua*) (Santos et al., 2010) where the m. teres minor and m. coracobrachialis are inserted onto the crest of the lesser tubercle of the humerus, and another difference is the origin of the m. coracobrachialis from the supraglenoid tubercle of the scapula. In the crab-eating raccoon (*Procyon cancrivorus*) there are no differences in these muscles (Santos, Bertassoli, Rosa, Carvalho, & Furlanetto, 2010; Windle, 1888) with *C. thous*. In the American raccoon (*Procyon lotor*) the m. teres minor is fused to the m. infraspinatus, and on the other hand, the m. coracobrachialis is inserted distally onto the tendon of the m. latissimus dorsi (Allen, 1882) being different to *C. thous*. In another procionid such as the kinkajou (*Potos flavus*), the m. teres minor was a non-segmented portion of the m. infraspinatus (Beswick-Perrin, 1871), which is a characteristic that did not occur in *C. thous*.

In members of the family Ursidae there are differences when compared to *C. thous*, such as in the black bear (*Ursus americanus*) where the m. teres minor has been found to be indistinguishable from the m. infraespinatus (Shepherd, 1883), differing from the polar bear (*Ursus maritimus*) in which it has a separate origin and insertion (Kelley, 1888). In these ursids there is a m. coracobrachialis longus and m. coracobrachialis brevis, where the first is inserted in a tendinous form onto the medial aspect of the humerus to the proximal part of the supracondylar foramen. The second is inserted onto the proximal part of the humerus (Shepherd, 1883; Kelley, 1888), which is homologous to the articular muscle of the humerus that report in the red panda (*Ailurus fulgens*), a member of the family Ailuridae (Fisher, Adrian, Elrod, & Hicks, 2009). In this last species the m. supraspinatus and m. subscapularis are inserted onto the articular capsule of the humeral joint (Fisher et al., 2009) similar to *C. thous*.

Conclusion

The intrinsic muscles of the scapular and humeral joint regions in *C. thous* have anatomical characteristics similar to those of the domestic dog and other wild canids, and therefore, they have similar functions. Nevertheless, an important difference is the finding of the m. supraspinatus conformed by two muscular bellies inserted together with the m. subscapularis into the articular capsule of the humeral joint, confirming the action that these muscles have in stabilizing this joint, giving it greater support in *C. thous* for its solitary hunting habits, such as has been reported in other families of wild carnivores. On the other hand, clinical and surgical procedures that involve the knowledge of these muscles may be homologous to those performed in the domestic dog, but the differences found in *C. thous* should be taken into approaches.

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